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THE NEW RAILROAD BRIDGE AT VANCOUVER.

By J. Mayne Baltimore.

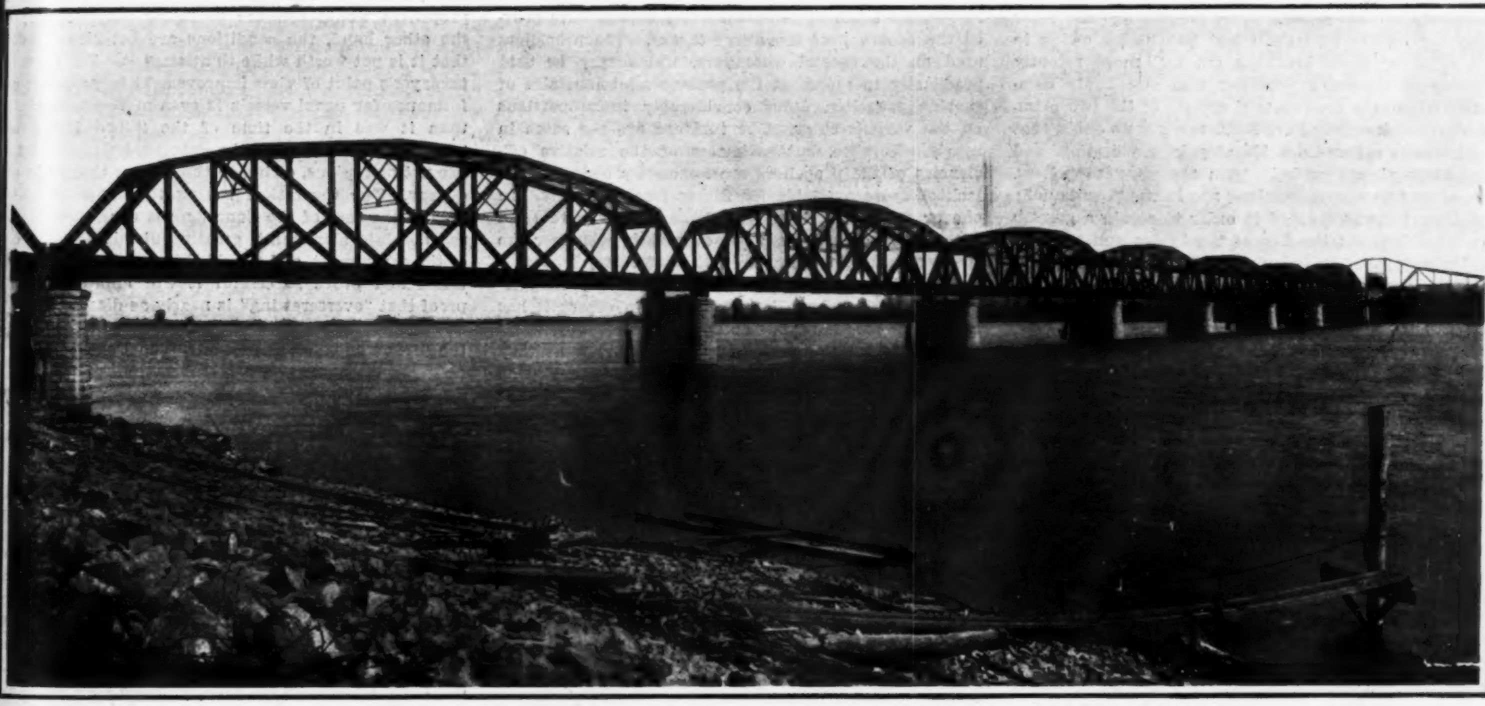
The great railroad bridge constructed by the Portland-Seattle Railway Company has just been completed, and thrown open to traffic. The railway belongs to the Hill System of western railroads, and will connect Portland, Oregon, directly with both Spokane and Seattle, Wash.

The new road was built along the north bank of the Columbia River, and for this reason it is generally known as the "North Bank Line." To reach Portland, it was necessary to cross the river at Vancouver, Wash. It is at that point that the giant bridge was built, and the immense viaduct, composed of cement, concrete, and heavy structural steel, required two years to complete, and involved an expenditure in round figures of $2,000,000.

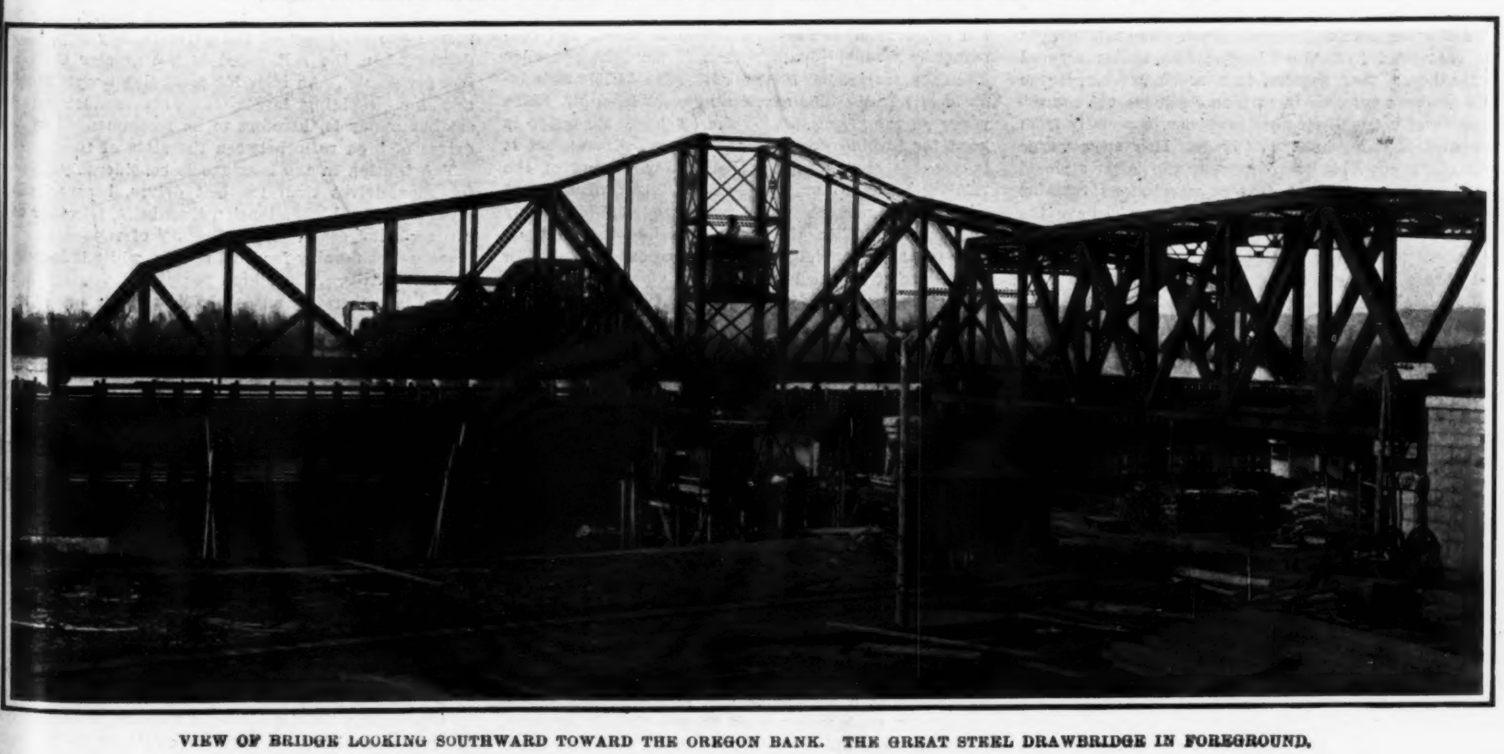
With the exception of the great structure across the St. Lawrence River, which collapsed in 1907, this viaduct is the largest, longest, and most expensive railway bridge on the American continent, if not in the world, and including the North and South Columbia River approaches, it is one mile and a half in length.

There are forty-eight giant piers, ten of which are in the main channel of the stream, while the remainder are placed across Hayden's Island, that lies near the southern bank, and across the wide slough on the Oregon shore. These thirty-eight piers are somewhat smaller and shorter than the ten huge piers in the main stream, but they are all of very ponderous construction.

The immense foundations of the ten giant piers in the principal channel were sunk 40 feet below the bed of the river, to bed rock, and are composed of strongly reinforced concrete, the reinforcement being twisted steel bars. They are built of this material up to within 40 feet of the floor of the bridge, and from that point are carried on up to the superstructure of huge blocks of granite massively united with cement.



VIEW OF BRIDGE ACROSS THE MAIN STREAM LOOKING NORTHWARD TOWARD THE WASHINGTON BANK.



VIEW OF BRIDGE LOOKING SOUTHWARD TOWARD THE OREGON BANK. THE GREAT STEEL DRAWBRIDGE IN FOREGROUND.

THE NEW RAILROAD BRIDGE AT VANCOUVER.

These great river piers range in length from 100 to 110 feet. They are 30 feet long at the foundation, 16 feet wide, and taper slightly as they ascend. All the other island and slough piers are constructed of reinforced concrete in a no less substantial manner.

The total width of the new bridge is 25 feet, and it is double-track. Near the northern bank, where the permanent channel is deepest, is a giant swinging steel drawbridge, the total length of which is 464 feet, which is ample to accommodate the largest vessels afloat. The circular pivotal pier, on which the drawbridge rests and swings, is 24 feet in diameter and built of reinforced concrete, steel, and granite.

The work of building the forty-eight piers, particularly the foundations, proved the most difficult, heaviest, and expensive part of this colossal task.

The Kelley-Atkinson Construction Company was the chief contractor, but much of the work was sublet. The entire operation was under the general personal supervision of the chief engineer of the Great Northern Railroad.

The steel used in the bridge weighs 25,000 tons, and this dead weight does not include the 80-pound steel rails of the double track which is 3 miles in length. With long and heavily loaded trains passing to and fro, some idea may be formed of the enormous weight that the huge piers must support. Many prominent engineers who have critically and technically examined this immense viaduct, pronounce it, for strength, massiveness, and permanency, a masterpiece of engineering.

This is the fourth railroad bridge that spans the Columbia River. One, built by the Canadian Pacific System, is near Nelson, in British Columbia; the second crosses the stream at Northport, and was built by the Great Northern. The third, at Marcus, was also built by the Hill System. These three bridges span the Columbia fully 500 miles above the new one just completed, and the stream is comparatively small at the points named.

The new bridge has been constructed at a height beyond the reach of the greatest floods and freshets known in the past.

TURBINE PROPELLERS.

A CRITICAL REVIEW OF RECENT DEVELOPMENTS.

THE extraordinary change that has taken place in recent years in the proportions of screw propellers for turbine steamers compared with those adopted for reciprocating engine vessels is about to be accentuated by an experiment that is being tried on the Cunard liner "Mauretania." When this vessel ran her trials she was fitted with four three-bladed propellers 17 feet in diameter by about 16 feet pitch, and she attained about 26 knots with 190 revolutions and 78,000 shaft horse-power. Some months ago the outer propeller on the port shaft lost two blades owing to the securing studs breaking off, and more recently the inside starboard propeller was also badly damaged. Whatever the practical success of the two mammoth Cunarders may have been, there is no doubt that both vessels suffered considerably from vibration, and this arose almost entirely from the wing propellers. The screws were modified long ago in the "Lusitania"; the diameter was reduced in order to obtain a greater clearance between the tips of the blades and the hull of the ship; but it is only just recently during her annual overhaul that a change has been made in those of the "Mauretania." Propellers of the original dimensions are being retained on the two inner shafts, but four-bladed screws have been fitted on the two outer shafts. The proportions of pitch, surface, and diameter are similar to those of the original screws, but the shape of the blades has been altered considerably. Hitherto almost every turbine propeller has been oval or circular; and whether wide at the tip or purely elliptical, it has had the area distributed symmetrically on each side of the center line of the blade. Nearly all have been three-bladed. The "Victorian" commenced her career with four-bladed screws, but they have not been adopted in any other turbine vessel save for occasional experimental trials, and those of the "Victorian" have now been altered to three blades. The change is being made more from the point of view of modifying the vibration than from propulsive considerations, but if is the latter which calls for attention. Additional facts bearing on the efficiency of turbine propellers are being eagerly sought for, and in this case the change should afford data of more than ordinary interest. The new screws are cast solid instead of having two blades secured to the boss; they possess, to a much greater degree than we have yet seen in turbine steamers, the characteristics of a tramp steamer propeller, especially from the point of view of shape of blade. How such a type with the narrow blades common to the latter style of practice will operate at turbine revolutions remains to be seen. Not a few marine engineers believe the "Mauretania" and "Lusitania" to be fitted with larger propellers than are really necessary. Both ship ratio and thrust per square foot of blade area were very low on trial even at the highest speed. Naturally, in a seaway, when the same power is being developed and the ship is retarded by the weather, both these items are considerably increased, but even then they are low compared with other turbine steamers, and it is considered highly probable that slightly smaller propellers, which would possess the additional advantage of running faster, would be more efficient in smooth water, and owing to their increased clearance from the hull, would not cause as much vibration as the original screws did.

At the last meeting of the Naval Architects Mr. R. E. Froude read a paper of particular value on the efficiency of propellers as deduced from model experiments. The main fact to be gleaned from his admirably compiled curves is that within very wide limits of pitch ratio the efficiency of propellers with a standard shape of blade falls off proportionately much less rapidly with reduction of pitch ratio, than for a standard pitch ratio it decreases with increase of area ratio, more particularly when the ratio of area to disk exceeds about 70 per cent. In other words, the practical designer is apt to be more correct if he adopts a large diameter in association with a medium area ratio and fine pitch ratio than if his area ratio is very big and his pitch ratio coarse. It is in absolute size and not in proportion that the Cunarder's propellers are thought to be too large, and with those figures of Mr. Froude's in our mind we cannot help hoping that in the interests of the profession any further changes will be systematic, so that we may get additional corroboration of model experiments from actual practice. So far, the trials of numerous other vessels have proved the accuracy of the above theory. The propellers used on the coastal destroyers, which may be said practically to represent the present minimum size of turbine propeller, differ considerably in proportions on the various ships. The turbines are the same in nearly all cases, but estimates of the relative efficiencies of the propellers are impossible owing to the lack of space available for fitting torsion meters. In one or two cases, however, similar ships were tried with different propellers; but even then, whatever the speed results may have been, the efficiency was still unobtainable. In some of these vessels very exaggerated area ratios have been adopted; in others it has been quite moderate, but neither can, we fancy, be as favorable from the propulsive point of view as they might be. The value of the data given by Mr. Froude is, so far, hardly appreciated at its full value; but it gives cause for reflection as to the scope apparently available for improvement in turbine propeller efficiency. The propellers of the "Kaiser Wilhelm II." have an efficiency of B. H. P. ÷ E. H. P. of about 64 per cent, those of the "Lusitania" and "Dreadnought" about 48 per cent. If only half the difference were attained—and we cannot help thinking that it will be attained, though not, perhaps, this time in the case of the "Mauretania"—the average daily coal bill would be reduced by about 120 tons—say, from 900 to 780 in twenty-four hours, taking only the propelling machinery into account. The vessel is running at least 180 days out of the year—rather more, perhaps—say, $120 \times 180 = 21{,}600$ tons per annum, and for two ships $=$ 43,200 tons of coal a year, which represents a saving of over $150,000 a year to attain the same speed. On the other hand, the same shaft horse-power and consumption would, if used with a 56 per cent propeller efficiency instead of 48 per cent, give 25.75 knots instead of 25. We take our basic figures from Mr. Bell's paper on the "Lusitania." The efficiency suggested is good for turbine work, though not exceptional, but it is not one that would appeal to the owners of the "Kaiser Wilhelm" or "Deutschland." An efficiency of even only 53 per cent would reduce the coal bill nearly 10 per cent. With the saving possible it would appear to us a financially sound step to experiment with propellers of modified form with a view to increasing the efficiency. For propellers of 17 feet diameter running at 180 to 190 revolutions 48 per cent efficiency strikes us as being ridiculously small. The efficiency in the case of the propellers of the later "County" class, which were only about 12 inches less in diameter and which revolved at nearly 150 revolutions, was well over 60 per cent, and it is difficult, indeed, to believe that the lower figure cannot be improved.

Much as Englishmen are gratified at the success of the Cunard Line, propeller efficiency in their case is merely a financial matter, but it is a national one in the case of the "Dreadnoughts." Instead of 21¼ knots on trial, the same higher performance we have suggested for the "Lusitania's" screws would give over 22. We do not suppose that the "Dreadnought" is much less superior relatively to the "Nassau" or "Voltaire," because she is only two knots faster and not three, but the odd knot might be useful, and if it is obtainable at a reasonable cost it is the duty of the Admiralty engineering staff to see that it is done. They are presumably more alive to that fact than other people, and from the new vessels of the class we anticipate that valuable information on turbine propellers will be obtained. There is nevertheless as much financial saving to be made by foresight as there is by experience, but with few exceptions propellers have not received the amount of practical scientific attention with the view to ultimate advantages that the turbine itself has. There is neither the time, nor, as a rule, the inclination to spend more money on a ship when once she has fulfilled the contract conditions, although it is often surmised that a change in propellers would conduce to better performance; on the other hand, the conditions are occasionally such that it is not worth while to attempt it. But from the taxpayer's point of view improvement in propeller performance for naval vessels is even more essential now than it was in the time of the "Good Hope" and "County" classes, while the data available for design are not as copious, owing to the radical change in conditions. The theoretical saving that appears attainable in the case of the Cunarders is considerable from the absolute standpoint, greatly outweighing the cost of the experiment, and should this eventually be undertaken and prove successful it will afford additional proof that "overscrewing" is nearly as disadvantageous as "underscrewing," not only as it was in the time of the "Iris," but also at present.—The Engineer.

EXPERIMENTS WITH ROPE AND BELT DRIVES.

SOME experiments have been undertaken by the Technical Institute at Charlottenburg, Germany, in order to establish definitely the loss of energy in transmitting power by means of belts and ropes. These experiments indicate that the capacity of belts for transmitting power at high velocity is considerably higher than given by ordinary formulas and calculating methods. It appears from the experiments that it is an advantage in belt drives to use large pulley diameters, and consequently high peripheral velocity. Considerably better results are obtained if the pulleys are made from wood for diameters less than 24 inches. An idler for obtaining the required tension, placed close to the small pulley and having a diameter at least 50 per cent greater than this pulley, does not reduce the efficiency of the drive in any appreciable degree when the belt speed is not greater than 100 feet per second. An idler for producing proper tension and for providing larger angle of contact on the smaller pulley is therefore to be recommended in belt drives of high ratio between the sizes of the pulleys.

The friction in the bearings is considerably greater for rope drives than for belt drives, because ropes must be under higher tension than belts, all other conditions being equal. The efficiency of rope drives decreases considerably for high speeds, while it increases for belt drives. When high peripheral velocity is required it is therefore advisable to use belts rather than ropes. In the case of rope drives the efficiency is also reduced when the diameter of the pulley or sheave is reduced, due to the power required for bending the rope, whereas the diameter of pulley in belt drives is of very little consequence, within rather large limits. The highest efficiency obtained during the tests referred to was 98 per cent with the belt drive, all conditions being ideal. Power transmission by means of a single rope gave 97 per cent as the highest efficiency; using two ropes side by side, made the highest efficiency 95 per cent; and only 90 per cent efficiency was obtained with four ropes side by side. The efficiency in the case of rope drives thus decreases about in proportion to the number of ropes employed. The figures quoted give the actual efficiency of the drive, the friction losses in the bearings being subtracted. The latter are also greater in the case of ropes than in the case of belts, due to the higher tension required in rope drives. While idlers in the case of belt drives did not appreciably decrease the efficiency, in the case of rope drives it was found that idler sheaves decreased the efficiency considerably.—Machinery.

HEAT IN STEAM.*

ITS MANY OPERATING CONDITIONS.

BY JOSEPH H. HART.

THE question of the amount of heat in steam under various operating conditions, the quantity of this heat available for transformation into work and the various relations of this heat quantity which produce condensation and superheating and other equally important changes in the steam content is a question of the greatest importance not only to the designing engineer, but to the operating and stationary engineer as well. As a general thing almost every man familiar at all with the operation of steam engines has a little information in regard to the subject of heat units and a number of heat changes and the amount of heat available under certain circumstances, but in regard to all the heat relations possible in steam under various conditions of operation they are not familiar. Thus such statements as the one that the quantity of heat in steam is approximately the same independent of its temperature is one not easily understood. Again, the statement that the specific heat of saturated steam is negative leads to an interesting situation and one not clearly understood by the average operator. These two examples will serve to illustrate the type of difficulties which arise, and it is the object of this article more fully to explain the connection of heat and steam, the variation of amount with temperature and the variability of the quantity available for transformation into work under various standard conditions and the causes of steam condensation under conditions not clearly understood.

Thus it is assumed that the average engineer or reader of this article is more or less familiar with the definitions of specific heat and latent heat and has a clear conception of what is known as heat quantity. Specific heat is defined as the quantity of heat required to heat one pound of material one degree Fahrenheit, measured in B.T.U., where a B.T.U. is the quantity of heat required to raise one pound of water one degree Fahrenheit. Thus heat quantity is referred to heat held by water under varying conditions, and the specific heat is often defined as the ratio of heat under certain circumstances to that in an equivalent mass of water under the same circumstances. Latent heat is defined as the quantity of heat required to change the state of a body without change in temperature, and it is generally known that this latent heat is given out in condensation or solidification, but absorbed in liquefaction or vaporization. However, this definition is not general enough and often leads to considerable ambiguity, whereas a broader statement of the case would explain many difficult facts as they arise and will not complicate the conditions at the outset in any respect.

LATENT HEAT POTENTIAL ENERGY.

A rise in temperature of a body is nothing more or less than an increase in the kinetic energy of the molecules. The temperature of a body measured by the absolute scale is directly proportional to the mean kinetic energy of the molecules, and these can best be regarded as little bullets flying around through space, in the case of a gas, and producing pressure by their multitudinous bombardment. In a liquid they are fastened together by some unknown bonds, probably similar to gravitation, but still free enough to possess a certain free path and hence capable of possessing kinetic energy. Thus, when a pound of water is heated one degree, a portion of the heat, or energy, is used to raise the kinetic energy of the molecules and a portion used to cause expansion or a stretching of the bonds which tie the molecules together. Latent heat is in reality potential energy of the molecules, or energy of position, and the molecules of water changed into steam possess potential energy of position in exactly the manner that a ball thrown above the surface of the earth, until it escapes the influence of gravitation, possesses energy of position. The molecules of steam have possessed at one time sufficient kinetic energy to rise from the surface of the water due to their motion, against the force of cohesion, hence losing a portion of their velocity exactly as a ball thrown into the air does in rising higher and higher.

When water is heated one degree, a certain amount of heat or energy is used in raising the temperature or kinetic energy of the molecules of the water, and a small fractional part is used up in producing the change of relative position and is apparent as potential energy. The molecules have a variable speed ranging over several thousand per cent, and the average or mean velocity or energy only is considered. When the water gets to the boiling point, some of the molecules possess sufficient speed to rise high enough above the mass of liquid to become practically free from their attractive power, and they lose during this maneuver a larger amount of their kinetic energy, possessing, after separation, approximately the same average kinetic energy as the average molecule in the liquid. The removal of the high-speed molecules means a diminution in the average speed of the remainder, and hence a fall in temperature unless heat is supplied. This supply, in reality, is the latent heat of steam. After the water is changed to steam, the steam then possesses practically nothing but specific heat, or rather increase in temperature means an addition only in the kinetic energy of the molecule. This is actually the case in what is known as superheated steam, in which case the steam behaves as a perfect gas and obeys Boyle's law and Charles's law absolutely.

WHAT HAPPENS IF THE PRESSURE ABOVE THE STEAM IS INCREASED.

If the pressure above the steam is increased, this fact means that the molecules are crowded together and a great many more collisions occur among the molecules endeavoring to escape from the surface of the water, and that a larger kinetic energy per molecule must exist for evaporation to go on, or simply that the temperature must rise before evaporation occurs. This is the reason for the rise in temperature of the boiling point with increase in steam pressure. The molecules, however, lose a similar percentage of their kinetic energy in escaping from the water and attaining their position, with its corresponding potential energy, as steam, and hence the latent heat or quantity of heat used up in potential energy is diminished, and hence the further phenomenon of a fall in latent heat or vaporization with rise in temperature of the boiling point. The fall in latent heat or potential energy required compensates largely for the increase in apparent heat or kinetic energy, so that the total heat in the steam is the same as the potential energy of position of the molecules plus their kinetic energy or energy of motion. This latter undoubtedly varies with rise in temperature, but the specific heat of steam at this temperature, or the quantity of energy required to raise the kinetic energy of the molecules the fractional amount required per degree, is so small a percentage of the total energy involved that it is often neglected.

It is possible under these circumstances, at least theoretically, to increase the pressure on steam to a sufficient extent to eliminate the latent heat of position entirely. If the molecules are sufficiently packed to prevent separation from the liquid, the energy of position practically disappears and the molecules increase their kinetic energy only, and this phenomenon occurs at what is known as the critical temperature, pressure and volume respectively.

ACTION OF STEAM IN CONTACT WITH WATER.

Steam in contact with water possesses anomalous behavior under varying conditions. The number of molecules in a given volume of steam at a given pressure, if the steam is saturated, that is, at the temperature of the water in contact with it, is a certain definite quantity which varies under certain conditions. The best explanation of the phenomenon here is that there are so many molecules in the steam that as fast as fresh ones arise from the water and produce steam, others from the steam enter the water and are condensed or lose their energy of position and acquire an increased energy of motion due to the attractive force exerted upon them. The molecules in the steam and water possess the same average kinetic energy, hence the same temperature, and only a certain number can exist in the steam, and the transfer of molecules to the steam from the water with the consequent loss in kinetic energy and production of potential energy of position, is exactly counterbalanced by the number of molecules of steam transferred from the steam to the water with their consequent loss of potential energy of position and equivalent rise in kinetic energy. Any increase in pressure on the steam or diminution in the volume of the same results in a crowding of the molecules from the steam into the water, with a corresponding increase in the average kinetic energy or temperature of the water and of the steam as well, since there are then less molecules in the steam and less potential energy in the system, with an increase in the average kinetic energy of all the molecules. This condition explains in reality what is known as the negative specific heat of saturated steam.

When steam in contact with water is heated one degree, the kinetic energy of the entire mass of molecules in both the water and steam is increased a certain definite percentage depending upon the absolute temperature of the system. The increase in kinetic energy of the molecules in the steam results in an increased pressure which means that a number of the molecules are transferred automatically to the water and give up their latent heat of position, which energy is apparent in increased average kinetic energy of the molecules. This energy results in a further rise in temperature. Hence when heat is added to a mixture of water and steam, or what is known as saturated steam, the amount of steam actually diminishes in quantity as determined by weight. The temperature of the water is raised a much larger amount than the heat put in would warrant according to the specific heat of the water, and the extra heat that is evolved in increased rise in temperature of the water and steam comes from the latent heat of condensation of the fractional part of the steam which disappears. Hence arises the statement of the negative specific heat or the production of heat with rise in temperature of saturated steam.

CAUSE OF MUCH DIFFICULTY IN DESIGN AND OPERATION.

This anomalous behavior of steam in contact with water is the cause of much difficulty in steam design and operation. Saturated steam, that is, steam in connection with the water in the boiler, changes in amount with every variation in pressure and volume of the same and does not behave as a normal perfect gas would under the circumstances. Thus with saturated steam entering the cylinder of a steam engine, the increase in volume which results from expansion in the cylinder and the transfer of a portion of the kinetic energy of the molecules into energy of the piston, results in a diminution in the kinetic energy of the molecules sufficient to cause a portion of the steam to change into water and to give up its latent heat, in order to maintain the temperature normal for saturated steam at this pressure and temperature. Hence the phenomenon of cylinder condensation which is augmented greatly by the further radiation of heat through the walls.

Sufficient has been shown to warrant the statement that the behavior of steam under all conditions of operation and theory is a purely mechanical one, and the transfers of kinetic to potential energy and *vice versa* are responsible for all the anomalous conditions existing in the utilization of steam. Any difficulty or misconception or ambiguity that arises in the utilization of steam can be explained and clearly understood by a reference to the kinetic and potential energy of the molecules. This latter conception, known as the kinetic theory of gases, is the basis of thermodynamics and has suggested many possible developments of a mechanical nature which are used in practical applications to eliminate the serious difficulties in power production in this field.

* Power and the Engineer.

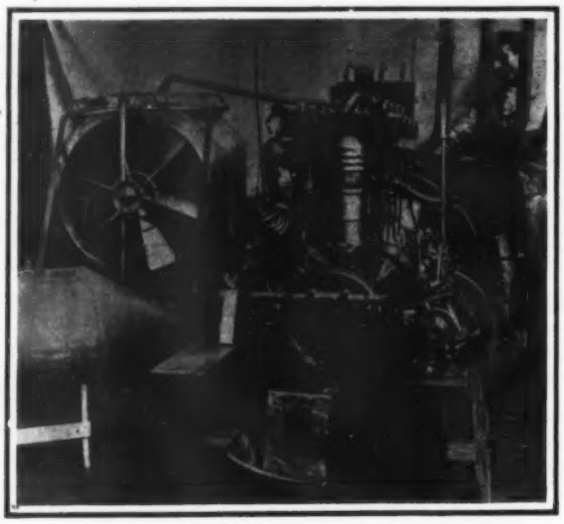
It is probably safe to say that until quite a recent date many a rolling-mill engine has lived its active life without ever having had an indicator applied to it to show what it was doing. Such engines were compared with each other in terms of cylinder diameter, stroke, revolutions, and boiler pressure, which while fairly suggestive of the maximum possible power which the engine was capable of exerting, gave little exact knowledge of the actual power being exerted at any less than a slowing-down load. In modern rolling-mill engines, even where the indicator is freely used, its indications must be carefully interpreted, for much of the irregular and intermittent work may remain constant for only a single revolution of the engine. The indicator will of course show a mean effective pressure in the cylinder, which effect is modified by the inertia of the reciprocating parts, the fly-wheel, the speed of revolution at a particular instant of time, etc., so that it would be quite a job to accurately interpret all of this into terms of torque at the surface of the roll. One of the nice things about the use of electric transmission of power is the greater possibility of reading accurately, at any moment, a record of just what is going on, and it is certain that as electric motors are still further employed in such work as this, there will eventually be accumulated a fund of very accurate and very valuable data for the use of future designers.

FOREIGN AERONAUTIC MOTORS.—III.

SOME OF THE LIGHTEST MOTORS OF THE 4-CYLINDER AND 2-CYLINDER TYPES.

BY THE PARIS CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

Although the automobile motor is generally of the 4-cylinder vertical type, not until the Wright brothers adopted this type for their aeroplanes did aviators begin to use it on their machines. Upon lighter-than-air craft, as soon as these became sizable enough to require considerable horse-power, the 4-cylinder water-cooled motor has been regularly used, and one of the photographs which we reproduce shows the motor of this type used upon the French airship "Republique."



END VIEW OF PANHARD & LEVASSOR 65-HORSE-POWER, 4-CYLINDER AIRSHIP MOTOR OF "LA REPUBLIQUE."

The radiator with fan and the gasoline tank are seen at the left, while the expanding shoe clutch that fits in the flywheel is shown upon the right-hand I beam of the motor bed. The location of the magneto on the left can be determined by the wires running up from it to the engine.

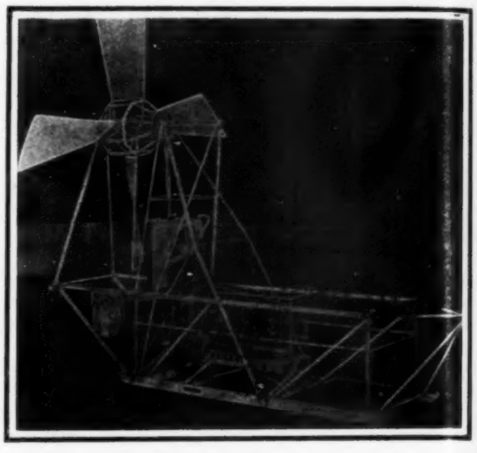
THE 4-CYLINDER PANHARD & LEVASSOR MOTOR.

The 4-cylinder motor used upon the new French airship "La Republique" is rated at 65 H. P. at 850 R. P. M. It is fitted with a high-tension magneto, centrifugal water pump, and Krebs automatic carbureter. The four steel cylinders have a 160-millimeter (6.299-inch) bore by a 170-millimeter (6.692-inch) stroke. The total weight of the motor and accessories is between 900 and 1,000 pounds. The cylinders are separately mounted upon the crank case, and each one is provided with a corrugated copper jacket silver-soldered to the steel cylinder. The inlet and exhaust valves are both mechanically operated. They are placed in chambers in opposite sides of the cylinders. The crankshaft is provided with separate bearings between each cylinder. This motor has been in operation on "La Republique" since last June, and has proved itself reliable and sufficiently powerful to drive this new 200-foot airship at a speed of over 30 miles per hour.

A GERMAN AIRSHIP ENGINE.

Two of our illustrations show a new 6-cylinder, German airship motor and the motor mounted in a frame and connected to a propeller for use on an airship.

This new motor, which has been designed and constructed by the Neue Automobil Gesellschaft, consists of six separate cylinders mounted upon an aluminium crank case. The cylinders have a bore of 130 millimeters (5.118 inches) and the stroke of the pistons is 150 millimeters (5.905 inches). At 1,300 revolutions per minute the engine is capable of developing from 100 to 120 horse-power, while at its maximum speed of 1,900 R. P. M. this power is considerably increased. The weight of the motor complete with magneto, pump, flywheel, carbureters, lubricator, and self-starting apparatus is 770 pounds, or about 6 pounds per horse-power. The valves are all mechanically operated from one side of the motor and they are located side by side in the cylinder heads. Three separate carbureters are provided, one being placed between each pair of cylinders. A very short inlet connection carries the mixture from each carbureter to the two inlet valves which it supplies. The cylinders are fitted with sheet-copper water jackets and the water is circulated by means of a large-diameter centrifugal pump which is gear-driven from one end of the cam shaft. The magneto is direct-connected to the water pump.



COMPLETE POWER PLANT FOR A GERMAN AIRSHIP.

It is of the high-tension type, and supplies current to the spark plugs located in the sides of the cylinder. A separate set of spark plugs is fitted for an accumulator and coil ignition system, if this is desired. A gear-driven pump operated by gears from the crankshaft forces oil to all the bearings of the motor. There are six large handholes in one side of the crank case and these make the bearings readily accessible for inspection. A large multiple-disk clutch is fitted in the flywheel, as can be seen from one of our illustrations. Staunchness and reliability were the main points kept in view by the designers of this new engine, and yet lightness has not been sacrificed, as the weight of 6 pounds per horse-power is not at all great when it is considered that the motor is capable of running for long periods while developing its full horse-power. The accessibility of all the parts is another good feature of the design.

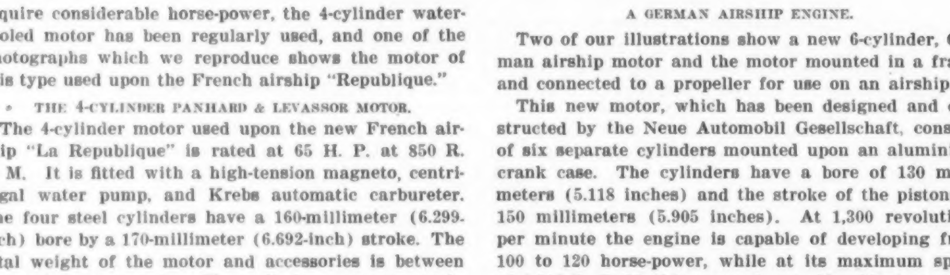
One of our photographs shows the motor mounted in a framework ready to be placed in an airship. The large four-bladed propeller is driven by a shaft and bevel gears from the motor crankshaft, while the fan back of the radiator can be seen driven from the flywheel by means of a belt. A cylindrical gasoline tank is placed horizontally at one end of the framework. The power plant shown is intended for an airship of between 3,200 and 4,500 cubic meters (112,108 to 158,917 cubic feet) gas capacity. This new airship is being constructed by the German Motor Airship Research Company. The diameter of the propeller shown is about 13 feet.

The motor is fitted with a self-starting arrangement consisting of a steel cylinder charged with compressed air or carbonic acid gas, which is admitted to the motor by means of a special valve.

THE DETEUIL-CHALMERS 2- AND 4-CYLINDER HORIZONTAL MOTORS.

One of the lightest foreign aeronautic motors is that made by the Deteuil-Chalmers firm, and which has been used successfully by Santos Dumont on several of his smallest and lightest aeroplanes. In the first light monoplane which he built, one of these motors of the air-cooled type and of about 20 horse-power, was fitted. Since then the company has brought out a twin opposed-cylinder motor of the water-cooled type. The photographs reproduced herewith give a good idea of the appearance of both these motors. The new one weighs 4 pounds to the horse-power, of which it is capable of developing about 58. The former air-cooled motor weighed but 48½ pounds, or 2½ to 2¾ pounds per horse-power.

The new water-cooled motor has two pairs of opposed cylinders placed side by side on a two-throw crankshaft, the cranks of which are set at 180 degrees. The connecting rods of each pair of cylinders are attached to one crank. In place of the usual heavy flywheel a light bicycle-type flywheel is used. The magneto is placed on top of the crank case and is driven by small spur gears. Cylindrical valves, both

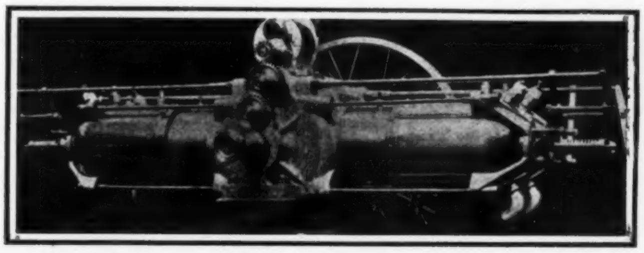


THE 17 TO 20-HORSE-POWER AIR-COOLED, OPPOSED-CYLINDER DETEUIL-CHALMERS MOTOR.

The motor is shown on Santos Dumont's monoplane, the propeller being mounted on its crankshaft.

SOME LIGHT 4-CYLINDER AND 2-CYLINDER MOTORS.

of which are mechanically operated, are located in the cylinder heads. The cylinders are attached to the circular crank case by long rods which pass through clamps placed over the cylinder heads. The spark plugs are located in the upper side of the cylinder heads. The water outlets are close to the spark plugs, while the water inlet pipes are on the under side of the cylinders at the bottom of the water jackets. Special oil pipes run to the cylinders for the lubrication of the pistons. The motor is fastened to the framework of an aeroplane by means of two bolts which pass through lugs in the crank case. The total weight of this motor is 108 kilogrammes (238 pounds) and the horse-power developed is 58, so that the weight per horse-power is about 4 pounds.



THE 58-HORSE-POWER TWIN OPPOSED-CYLINDER DETEUIL-CHALMERS WATER-COOLED MOTOR.

The two spark plugs, concentric valves, and exhaust elbows at the ends of the right-hand end of the motor show that there are two parallel cylinders. The gears that operate the crankshaft and magneto are shown exposed on the side of the crank case.

THE VIVINUS 4-CYLINDER MOTOR.

Another new 4-cylinder motor that has been developed from an automobile motor is the "Vivinus," which is made in Belgium. This motor is not particularly light, the 50-horse-power engine weighing about 300 pounds, but it is capable of running for a considerable length of time without any decrease in power. It is being used by Mr. Moore-Brabazon, the new English aviator, on his Farman-type machine, with which he has recently made several short flights.

THE ANZANI 3- AND 6-CYLINDER MOTORS.

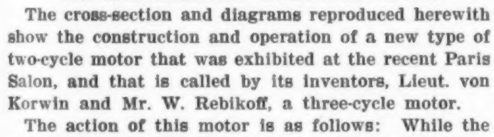
Another new light-weight motor that has met with some success is known as the Anzani. This is a triple-cylinder motor, in which two of the cylinders are set at an angle of 45 degrees, while the third one stands vertically between them. Water-cooled motors of from 12 to 50 horse-power of this type are built, but they have not as yet been used on any leading aeroplanes.

THE KORWIN-REBIKOFF THREE-CYCLE MOTOR.

The cross-section and diagrams reproduced herewith show the construction and operation of a new type of two-cycle motor that was exhibited at the recent Paris Salon, and that is called by its inventors, Lieut. von Korwin and Mr. W. Rebikoff, a three-cycle motor.

The action of this motor is as follows: While the crankshaft is turning from *A* to *B* (see diagram, Fig. 1) the gases explode and expand. From *B* to *C* the exhaust takes place and the fresh charge of gas is drawn in; while from *C* to *A*, this fresh charge is compressed. The cycle differs from that of the two-cycle motor in that the suction of the fresh charge begins and ends before the exhaust is completed or simultaneously. In other words, with the three-cycle motor the suction stroke is a little ahead of the exhaust stroke, or rather it occurs at the same time, while with the two-cycle motor the suction stroke occurs after the exhaust.

This new type of motor has an auxiliary piston *A*



DIAGRAMS SHOWING THE OPERATION OF THE THREE-CYCLE MOTOR.

Fig. 1.—Circle showing position of crank at each point of the cycle. Fig. 2.—Diagram of pistons and valves. Fig. 3.—Curves showing relative movement of the pistons.

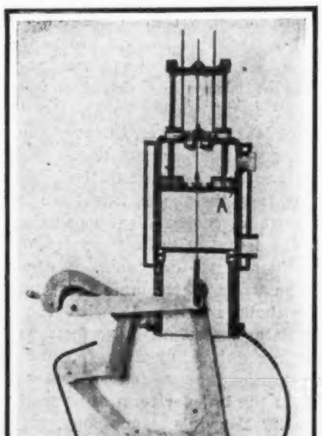
(Fig. 2) containing a valve *a*. This auxiliary piston is placed between the main piston, *P*, and the cylinder head, *B*, and the movement of the two pistons is intimately connected. The valve *a* opens downward. The main inlet valve *b* is located in the cylinder head, while the exhaust port, which is the same as that of an ordinary two-cycle motor, is located at *C*. The spark plug is placed at *F* in the cylinder wall.

The operation of the auxiliary piston is as follows: When the crankshaft turns from *A* to *B* (Fig. 1), the piston remains stationary. During the next third of a revolution of the crankshaft the auxiliary piston moves downward, and during the last third of a revolution upward with the main piston.

Fig. 3 represents by means of two curves, *M N* and *K L*, the movement of the main and auxiliary pistons. The abscissas represent a complete turn of the crankshaft, which is divided into twenty-four parts, while the ordinates show the movement of the two pistons with respect to each other and to the cylinder head. When these are at the top of the stroke, and during the first third of a revolution, the space between them is represented by *A H*. The ordinate *O P* shows the height of the exhaust port. The points *A B C* show the position of the piston when the crankshaft is at *A*, *B*, and *C*, Fig. 1, and the points *a*, *b*, *c* show the corresponding positions of the auxiliary piston.

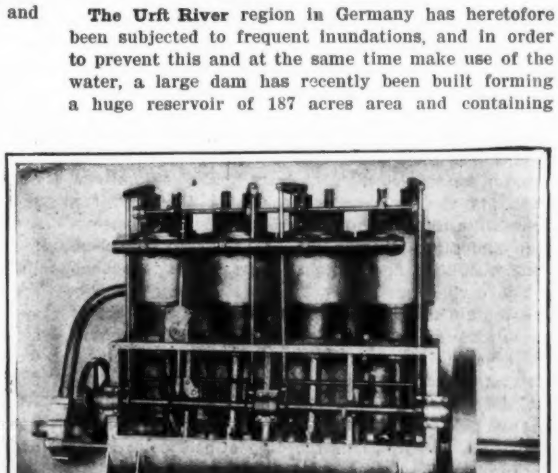
The direction of revolution of the crankshaft is indicated by an arrow. The setting of the two pistons is such that the auxiliary piston has a lead of 1/24 of a turn over the main piston. During the first third of a revolution of the crankshaft (1-9) explosion and expansion take place, the main piston moving from *A* to *B*, at which point the exhaust occurs. During this time the auxiliary piston remains stationary. Just before the main piston reaches the point *B*, however, the auxiliary piston starts to descend and draw in fresh gas through the inlet valve, *b*, in the cylinder head. During the second third of a revolution (9-17) the main piston uncovers the exhaust port and, after the crank has passed the lower dead center, it begins the return stroke, the exhaust being completed at the point *C*. The auxiliary piston has finished its suction stroke and has started to return when the main piston has reached this point. During the return stroke of the auxiliary piston the valve *a* (Fig. 2) in the latter opens and the gas above this piston is transferred to the space between it and the main piston. Just before the auxiliary piston started to ascend, however, it was in such close proximity to the main piston that any exhaust gas remaining between the two must necessarily have been crowded out of the exhaust port.

During the last third of a revolution (17-24), the auxiliary piston rises to the top of the cylinder and remains stationary. The valve *b* closes and the fresh gas passes through the valve *a* into the space between the two pistons, where it is compressed and



CROSS-SECTION OF THREE-CYCLE MOTOR.

The auxiliary piston is shown at A. While the exhaust is escaping through the port on the right, piston A is descending and drawing in a fresh charge through the inlet valve in the head.



WRIGHT BROTHERS' 28 TO 30-HORSE-POWER 4-CYLINDER AEROPLANE MOTOR.

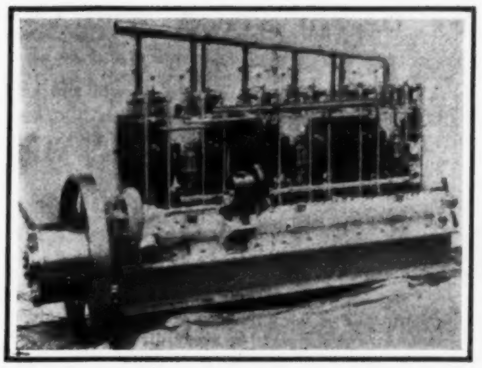
This motor is now being manufactured in France for the Wright aeroplanes.

SOME LIGHT 4-CYLINDER AND 2-CYLINDER MOTORS.

exploded. The suction therefore takes place in the chamber between the head of the cylinder and the auxiliary piston, and the compression and explosion in that between the auxiliary piston and the main piston.

The motor can be throttled by varying the stroke of the auxiliary piston so that it does not approach so near to the cylinder head, the result being that not all the gas passes through valve *a* into the working chamber. Hence the power of the motor is varied by changing the cylinder volume.

The main points about this new motor are the following:



THE N.A.G. 120-HORSE-POWER 6-CYLINDER AIRSHIP ENGINE.

Note the multiple-disk clutch in flywheel and the centrifugal water pump and magneto driven from the cam shaft. An aluminium carbureter is seen between each pair of cylinders near the top.

1. One explosion per revolution of the crankshaft.
2. Wide power variation at nearly maximum efficiency without changing the compression or point of ignition.
3. Complete expulsion of the burned bases.
4. The quantity of the inspired gases does not depend upon the resistance of the exhaust gases.
5. The suction is very energetic, as the conditions on this stroke resemble those in a 4-cycle engine.
6. The spark plug is in contact with the fresh gas during two-thirds of each revolution of the crankshaft.
7. The fresh mixture does not come in contact with the burned gases as in the usual 2-cycle motor.
8. For the same power, the weight of this motor is considerably less than that of a 4-cycle motor.
9. On account of the construction and operation, automatic valves can be used instead of mechanically-operated valves.

The auxiliary piston of this motor is operated by rods extending upward outside of the cylinder and connected to a yoke, and there is also a peculiar system of levers shown in the cross section.

Although a model motor of this type has been constructed nevertheless it appears to us rather complicated, and it is doubtful whether it will ever find wide practical use. The chief advantage of this new type of motor lies in the fact that more power can be got out of a given sized cylinder than can be obtained from an ordinary 2-cycle motor. The 2-cycle motor, it is well known, is gradually coming into vogue for both automobile and aeronautical purposes.

The Urft River region in Germany has heretofore been subjected to frequent inundations, and in order to prevent this and at the same time make use of the water, a large dam has recently been built forming a huge reservoir of 187 acres area and containing 60,000,000 cubic yards of water. The dam is 1,100 feet long and 177 feet high. A power plant has been established near the dam and uses this water to generate electricity. The power plant contains six 2,000-horse-power sets and provision has been made for two more.

DARWINISM FIFTY YEARS AFTER.

THE BIOLOGICAL LESSON OF EVOLUTION.

BY DAVID STARR JORDAN, LL.D., PRESIDENT OF LELAND STANFORD, JR., UNIVERSITY.

It is a century since the birth of Darwin and half a century since the publication of the "Origin of Species," the great book of the nineteenth century, and one which changed the entire face of biology and of philosophy.

We may consider in a hasty way the condition of biology before Darwin, then with Darwin, and then fifty years after.

Before Darwin there were great naturalists, as eager to trace the thoughts of God and their ramifications throughout nature as any who have labored since. But while everywhere and in every direction the path of investigation was crowded with facts, all answers to the question "Why?" seemed hopeless. The simple problem of the meaning of likeness in animals and plants seemed without possibility of answer, or only of such answer as, couched in the language of metaphysics, was devoid of practical meaning.

That the world of life was divided into multitudes of species, that these species could be classified into groups of various grades by their structure, that long-enduring strains of likeness were traceable among them, that species themselves, though long persistent, were not immutable—all these were facts known to every scholar. But that the mighty differences among living things were derived through minor changes, in slow processes of divergence, very few dared to believe. Those who for one reason or another speculated in this direction were one and all unable to show any adequate causes behind such mighty effects.

Hence scientific men, following the fashion of the unscientific, settled down to the idea that each species of animal and plant had arisen to begin with by a process called "special creation." The scientific world never believed in "special creation." The phrase was recognized as meaningless, and the process itself beyond the possibility of definition or of imagination. But anything else was also non-imaginable, and most men of science kept on with their special work and let it go at that. Agassiz, almost alone, figured to himself an actual special creation of groups of eggs or germ cells, under conditions unknown, but at least regular, and in accordance with the thoughts of God. "Material form" was to him ever "the cover of spirit." To Darwin material form was ever the lurking place of a cause of which the form was the natural resultant, and perhaps the more metaphysical phraseology of Agassiz meant the same thing after all.

Darwin showed us, what all naturalists half knew before, that the unit of variation is lower than the species, and that the species has no kind of permanence different from that of the race or the genus or the family or the tribe. In the world of life there are no two individuals alike, nor is the same individual quite the same through any two successive periods. If no two individuals are quite the same, there must be a reason for it. If the members of a group, having a common origin, change in time, and change in space, diverging as they spread over the earth, there must be a reason for this also. That every kind of animal and plant fits the environment, whatever it is, as the "dough fits the pan" or the river its bed, is also evident, and for this again there must be some reason. That with time and space all forms seem to change and to divide into branches is also evident, and this also must have its causes. That, again, all variant forms we know in all the earth are reducible to a very few types, is also evident. It is plain that in whatever image man was made, the monkey, the dog, the cat, the bear, the mouse, and even the bird, the turtle, and the fish, are made in substantially the same image. And behind all this it is the duty of science to insist on knowing the reason why.

"One of the noblest lessons left to the world by Darwin," says Cramer, "is this, which to him amounted to a profound, almost religious conviction, that every fact in nature, no matter how insignificant, every stripe of color, every tint of flower, the length of an orchid's nectary, unusual height in a plant, all the infinite variety of apparently insignificant things, is full of significance. For him it was an historical record, the revelation of a cause, the lurking place of a principle."

The clue to all this was found by Darwin in natural selection, the survival under any condition of the individuals best adapted to these conditions, and the persistence through heredity of the traits of those to whom survival and adaptation were possible.

Darwin showed that thousands or millions of seeds were cast for every plant that matured, hundreds or thousands of eggs were laid for each animal that survived, tens or hundreds of animals were born for each one which came to maturity. He showed that the destruction of the mass with the preservation of the fit was not all the operation of chance, but went on under definite rule. Competition is at work everywhere and favors the individual who can best make headway as young or as adult in the conditions that actually are. The struggle for existence is ever present, is ever varied, the struggle of like with like in a congested district, the struggle of like with unlike, the struggle of all with the varied conditions of life. Out of all this, by natural causes, arose the variety in life as we know it to-day, the variance of individuals, the differentiation of species, and the fitting of some living forms to all conditions, from the snows of Orizaba to the abysses of the deepest sea.

Darwin found that species could be altered, divided, or modified by conscious and purposeful mating, with the destruction of the undesirable. This represents the art called "artificial selection," "the magic wand" by which the breeder effects his creations. For the cognate process in nature, unconscious but none the less efficient, he chose the term "natural selection." In his mind "natural" or actual was balanced against supernatural or imaginary, for to him an actual result must ever be associated with a tangible cause.

Animals and plants vary, and in all directions nature selects those whose variations are most favorable for the continuance of the species. More exactly, those individuals unfavorably built or unfavorably placed are first to die. Those who are left determine the future of the group. Like produces like. *Like the seed is the harvest.* This is the law of heredity, and the inheritance of one generation is from the individuals which survived in the generation which came before. The bonds of unity among living forms find their explanation in heredity. Homology or fundamental likeness of any sort means blood relationship.

The essential factors in the procession and divergence of living forms which we call "organic evolution" are therefore (1) variation, which Darwin took as a fact without explanation; (2) heredity, which he also took as a fact, with an attempt at explanation, as nearly adequate as the scanty knowledge of histology in his day would permit; and (3) selection. Heredity and variation are innate, or intrinsic, causes. They are involved in the nature of organic life. Selection is an external cause, operating as a motive force, pushing groups of organisms along as the force of gravitation rushes the water of a river to the sea. Without such motive force, evolution would get nowhere. Nothing happens *in vacuo*. A train of cars would not move were there no friction on the rails. "Heaven forfend me," Darwin once declared, "from the Lamarckian nonsense of innate tendency toward progression."

Under natural selection Darwin grouped all natural, or extrinsic, causes affecting the movement of life. The finer analysis of later times detaches from selection another factor indispensable to it, the "*raeumliche Sonderung*" of Moritz Wagner, the condition known as separation, segregation, or isolation. It is isolation always that renders selection effective. Without some form of separation, the chosen fittest are lost again in the mass. Without geographical separation, we could account for the actual origin of very few of our actual species of wild animals or plants. Without artificial separation the work of the animal or plant breeder would be without result. So with the process of selection in nature. But all these facts were more or less clearly recognized by Darwin, and to detach natural "separation" as a friction-factor in organic evolution from the broader term of natural "selection" is but to clarify Darwin's terminology, without changing the essential meaning of Darwinism.

"The four factors named," says Dr. Ortmann, "variation, inheritance, selection and separation, must work together in order to form different species. It is impossible to think that any one of them should work by itself or that one could be left aside."

These words, written nearly fifty years after the "Origin of Species," gave a compact statement of the essential doctrine of Darwinism; and this statement seems still to be absolutely true.

Now, after these fifty years of biological investigation, of intensive work in observation and experiment such as never was known before, observation and experiment all directed toward the opening door of "Why?" to enter which the origin of species gave us the first clear warrant of authority, where do we find ourselves? What is to-day our conception of organic evolution? When a new land is opened to exploration, its first map, sketched from some mountain peak perhaps, shows the general features of the land, but without special detail, unless it be about the mountain peak itself. Such a new land was opened by Darwin in his survey of the methods and processes of organic evolution. The survey of special details was begun in his own garden at Down. In a large way, the salient features of the land were sketched with amazing truthfulness. The rivers run where he placed them. We have his word for valley, forest and cliff, and in all these larger features fifty years have wrought no very material changes. Men have sought to change the map. Shrill voices from every civilized nation have risen in criticism. Here a forest would be moved, here a lake and there a river. But better studies have shown the largeness of Darwin's vision. These critics could not see the landscape for the brush. Or, dropping the allegory, already too cumbrous, we may see that our knowledge of organic evolution has grown by leaps and bounds, but chiefly along lines laid down or foreseen by Darwin.

Since Darwin's time, the compound microscope has opened the secrets of histology. We have given meaning to the "physical basis of heredity." We have learned the process by which two germ cells from two different individuals divide and mingle to form a new individual, and we have followed this process through many complex and unforeseen ramifications. We have settled many difficult questions, and we have raised a thousand more, which may yet in turn be settled, but with the same result of raising thousands of new questions. We have found reasons why no two individuals can be alike, why no two germ-cells can ever be alike, and we have some hint as to why characters will be latent in one generation to reappear in the next.

With the microscope and its accessions we have traced the life history of thousands of species, from the germ cell to adult life, thus adding the third of Haeckel's "ancestral documents," which define for us the actual nature of any animal. These are morphology, the knowledge of the animal's actual structure; paleontology, the history of its ancestry; and embryology, the history of the stages by which the individual is made up. For "*unter jedem Grab liegt eine Weltgeschichte*" (In every tomb lies a world history).

With the development of histology, morphology, and embryology, we have developed the physiology of all sorts of organisms. We have learned what organs of all sorts can do, and experimental physiology is ever getting nearer and nearer the meaning of the condition we call life. But with all our increase of knowledge, we are no nearer the end of the problem. Some men believe in vital force, because they come into contact with phenomena explainable through no other force. Others reject vital force, because the existence of such a force is inconceivable. And so it is, and equally inconceivable is its non-existence. As Prof. Brooks, wisest of American naturalists, used to say, "We shall never know the truth in this matter until we find it out."

The Lamarckian belief in the heredity of results of use and disuse, and of the impact of environment, accepted by Darwin without question, has been practically eliminated from Darwinism. After fifty years we have no clear case of any such inheritance of characters not unborn in the parent. And yet, with the death of the Lamarckian hypothesis, the same principle arises in new forms. One of the interesting problems of the day is the effect of changed environment in promoting germ variation. Inheritance of acquired characters in kind may not take place. The evidence seems all against it. But the thesis that external conditions do not cause germinal reactions is not yet clearly established. The discovery of Gregor Mendel as to dominant and recessive characters in peas has proved a valuable basis for investigation in the methods of heredity. But no change in the theory of Darwinism is made necessary by it. The hypothesis that the characters of species may be described as units, and that they may be transmitted as units by certain portions of germ plasm, is a convenient one as a framework for investigation. It is a sort of atomic theory of animal life, not true, but capable of being treated as true until we have a better idea of what the truth really is.

The investigations of Dr. De Vries have proved of great importance in suggesting fruitful lines of investigation. The study of pedigreed animals and plants cannot fail to give us many new ideas of

heredity and variation. Darwin recognized many different grades of variations among animals and plants. These range from the sudden large change which De Vries calls mutation to the minute fluctuations which separate individual from individual. But Darwin saw no fundamental difference between the wide and the narrow oscillation, nor has such difference been clearly shown by any one. With all admiration for the painstaking and illuminating work of De Vries, I do not think that the question of the origin of species has been affected by it. Species in general do not arise through mutation, or the abrupt separation of one individual from the rest of its kind. If any single species should be shown to have arisen in this way, it would not change the general relation of the recognized factors in evolution, for a mutation, like any other variation, is dependent for preservation on heredity, on selection and on separation or isolation.

Since Darwin's time, natural selection has been exalted as all-powerful by many writers who, as Darwinians, went far beyond Darwin himself. In reaction, other authors have denied to selection, not merely "*allmacht*," or all-sufficiency, but any sufficiency or reality at all. It is enough for our discussion to disclaim all these extreme views. Selection must find its place in the heredity of any individual or species. We know no other cause for the myriad adaptations of life to its environment. We know no other reason for progressive adaptation. And yet the actual traits of actual species are largely non-adaptive.

The splitting of forms into different species is everywhere associated with geographical separation. One form may be as well fitted as another, one set of color markings as convenient as another, but if barriers of land, or sea, or climate, or food shut off one from another, each will persist in its own place, in its own way.

The study of the geographical, faunal and geological distribution of life on the earth, which has been pursued with such energy and with such success since Darwin's time, has laid greater and greater stress on the effect of barriers in producing species. With this, the effect of constant pressure in the same direction, extending through long periods of geological time, has been dimly perceived and recognized under the term Orthogenesis. If all individuals could move anywhere on the earth without friction, all animals closely enough related to interbreed would assume a common character. There is everywhere friction in geographical distribution. As dialects form in human speech, where men cease to mingle evenly, so species form among animals or plants where there exists a check to migration. The separation of forms by barriers is a natural process, but it is not a part of natural selection, but rather a distinct factor, natural separation. But the extension of our knowledge of this or other factors has not changed the general situation, for the general facts of geographical distribution were clearly recognized by Darwin. It is, in fact, from a study of these phenomena as shown in species inhabiting the coasts of South America that Darwin was first drawn to the problem of the origin of species. Prof. Conkin observed not long ago, "On the whole, then, I believe the facts which are at present at our disposal justify a return to the position of Darwin." This he said with reference to a special problem in heredity, but these words apply to many others. "The position of Darwin" is very safe standing ground. What we have learned with better tools and keener insight into minor details has not changed the large problems very much, and this, as Conklin said again, is "but another testimony to the greatness of that man of men, that, after exploring for a score of years the ins and outs of pure selection and pure adaptation, men are now coming back to the position outlined and unswervingly maintained by him."

The chief and essential contention of Darwin, that species are formed by natural tangible processes, is now absolutely beyond question from those competent to form an opinion. That the animals and plants today, man included, are descended from the animals and plants of earlier periods by natural lines of descent with natural modifications, due to innate and external causes, is one of the certainties of science.

ELECTROCULTURE OF PLANTS.

AN ACCOUNT OF SOME RECENT EXPERIMENTS.

The first experiments on the influence of electricity upon the growth of plants date from the year 1885, when Prof. Lemström, of Helsingfors University, demonstrated the favorable results obtainable by "electroculture." Since then little progress has been made in this field, notwithstanding the fact that a number of investigators have given it their attention, and that the modern developments of electrical engineering have placed at our disposal many new resources. In fact, until recently the work had nowhere passed beyond the purely experimental stage. Of late, however, investigations have been carried out on a large scale in England by Sir Oliver Lodge in conjunction with the well-known agriculturist J. E. Newman and Mr. R. Bromford, the last mentioned of whom is the owner of large estates. The experiments have been planned under conditions resembling as closely as possible those met with in actual practice. The work was begun in 1906, using at first a plot of about ten acres. Latterly this has been extended to about twenty-five acres. The electrical installation is in general character similar to that used by Lemström. It consists of a system of wires strung from insulating supports over the field. This system is connected to the positive pole of a small dynamo, giving three amperes at 220 volts. The other pole of the dynamo is earthed. The motive power is supplied by a 2-horse-power benzine motor. The alternating current from the generator is transformed up to 100,000 volts, and is then rectified by means of a special mercury rectifier due to Lodge. This high tension is quite free from danger, as the quantities of energy involved are very small. Its advantage is that the wires can be placed at a considerable distance from the ground without greatly diminishing the effect on the plants. The distance chosen was 17 feet, which gives ample space for carrying out all the necessary labor, and for the passage of heavily-loaded wagons beneath the wires. This represents a very important step forward, as it was necessary hitherto to place the wires within about two feet from the ground, an arrangement which is obviously so inconvenient as to practically bar it from actual use on a commercial scale. The proper insulation of the wires carrying the high-tension current presents no difficulty with the means which modern methods place at our disposal.

When the current is turned on, a discharge occurs from the wires to the ground, often accompanied by a crackling sound, and at night by a glow. In 1906 the field was sown partly with English, partly with Canadian wheat, and exposed to the action of electricity on 90 days, in all during 622 hours. At night the current was switched off. The experiments seem to show that favorable results are obtained if through the summer the discharge is allowed to take place during the hours of early morning, while in spring and on dull days it is best to continue the discharge all day. The principal effect appears to be produced on young plants. The seedlings raised under the influence of electricity were found to be more deeply colored and altogether more vigorous than those grown for comparison in a blank experiment. At a later stage the stalks measured 10 to 20 per cent more in length than those in the check experiment. When flowering began, the current was turned off. The ear began to form about the same time both in the treated and the untreated field, but the grain was ripe for cutting three or four days earlier in the former than in the latter.

The increase in yield thus produced by electroculture was 39.2 per cent in the case of Canadian wheat, and 29 per cent in the case of English wheat. The product is said to be also of better quality.

The experiments were repeated in 1907, and were also extended over a large strawberry bed. The current was supplied on 115 days during 1,014 hours in all. There was 29 per cent increase in the crop of Canadian wheat. The strawberry crop exceeded that of the check experiment by 35 per cent. Good results were also obtained with tomatoes and raspberries. In the case of the latter it appeared that the older plants were not affected, while there was a strong influence on young stocks.

An entirely different method of electroculture has been followed by an Italian investigator, Philipo Campanile. A very considerable improvement in the crops on poor, unfertilized soil was obtained by burying under it at intervals plates of zinc, copper, and iron connected by inducting wires. The copper-zinc pairs were formed throughout to give better results than the copper-iron couples. Campanile's observations agree with those of Lodge in that the principal effect appeared to be on the young plants, germination taking place two to four days earlier under the influence of electricity than under the ordinary conditions.

Another application of electricity to agriculture was exhibited by Le Roy at the exposition at Marseille. Especially good results were obtained by Le Roy's method in the case of asparagus and strawberries. In this case it is not the direct action of electricity that is brought to bear on the plants, but the heat generated in a network of resistance wires buried in the ground. It seems somewhat doubtful whether equal results might not be obtained here by other, more economical methods of heating.

The question of expense will no doubt be the principal factor in determining whether or not electroculture is to be ultimately introduced in practice, now that technical difficulties have been removed by Lodge and his collaborators. As regards running expenses the system placed under trial in England seems to be very satisfactory, considering that an increase of 30 to 40 per cent in the output was attained with an expenditure of only about two thousand horse-power hours. The conditions appear a little less favorable as regards cost of installation, which may run somewhat high for posts, wires, insulators, etc. As regards the power plant, it should be possible to make this repay fully its own cost, by using it in fall and winter for a variety of agricultural duties, such as threshing, grinding, cutting, etc., to say nothing of furnishing light. The cost of maintenance of the wires would probably be small. The outlook seems favorable, and we may expect before very long to hear of large-scale practical applications. Probably, however, the first developments will be not so much in general agriculture as in horticulture, in market gardening, and in raising "forced" products in our temperate latitudes.—Translated for Scientific American Supplement from Prometheus.

PETROLEUM IN 1908.

The great gain in production of petroleum in 1907 over 1906 required such a drain on all the great pools and developed so large a stock of unused crude oil that a further increase in 1908 was not logical, as a matter of either finance, trade requirements, or available petroleum resources. As the year went on, unprecedented floods in May and June and again in November brought disaster to the pipe lines of Oklahoma; and these storms also left a record of numerous oil tanks destroyed by lightning. In the eastern fields the severe drought also seriously interfered with well drilling. The decline in production in the Glenn pool and in various Texas and Louisiana pools increased the likelihood of a total smaller than in 1907.

Nevertheless, the actual record of the year shows a total beyond all records—between 175 and 180 million barrels, compared to 166 millions in 1907, or between 5 and 9 per cent increase. The total value is proportionately greater still, for the price of the product in California increased and it remained steady in other fields, except the Gulf, where a comparatively groundless fear of overproduction from the new Markham and Goose Creek fields caused depression.

The increase came from the steady growth in Illinois and California. Neither field showed phenomenal development. California responded to the higher prices consistent with depleted stocks, and Illinois showed the continued effect of the great investments of the previous year in this new territory.

The year, however, had its sensations. They came in midsummer. On July 2nd a large gusher was drilled in at Goose Creek, Harris County, Texas, and three days later a gusher of the Spindletop type came in at Markham, in Matagorda County. This turned the attention of the oil producers in the Gulf field significantly farther south.

July 4th proved memorable in three widely separated regions. At Anse la Butte, La., a large gusher known as Lake No. 9 was drilled in. On the same day the Pearsons in Mexico opened a well that assumed the proportions of a volcano and made a new world's record for an outburst of oil and water. Incidentally it is interesting to note that on the same day the Oil City well at Tustanowicz produced the record spouter for Galicia.

The elasticity of the American oil trade is shown by the fact that stocks did not increase as much as would have been expected from the great product. The preparations of the year before led to better ability to transport the product to points of consumption.

In the isles of the Pacific and certain regions of South America the natives use a so-called "candle-nut" to furnish them with light. This nut burns without smoke or odor, giving a good white flame. It is provided by nature with a channel or perforation which forms a very convenient space for inserting the point of any suitable object to support the "lamp." The nut also serves as food to the natives.

THE LIFE HISTORY OF THE TERMITE.

A FORMIDABLE TROPICAL PEST.

BY PROF. K. ESCHERICH.

Termites are among the most formidable pests of hot countries. Nothing is safe from them except iron and stone, for they devour even glass with the aid of their saliva. They have destroyed the governor's palace in Calcutta and an English ship at Bombay. Introduced into St. Helena, probably by a slave ship, they multiplied enormously and soon reduced Jamestown to ruins. Furniture, clothing, books, flour, and grain are quickly devoured by them. An Arab is said to have been stripped naked by the insects during a nap on a termite hill.

The nature of termites and their place in the zoological system are generally misunderstood. They are commonly called "white ants," but they are as far removed from ants as the kangaroo is from man, for they are among the lowest of insects, and ants are among the highest. The ant goes through a complete metamorphosis. The larva which creeps from the ant's egg is a footless grub, totally unlike the perfect insect which it ultimately becomes, after passing through the motionless form known as the pupa. The newly hatched termite, on the contrary, is very like the adult except in size and the absence of any trace of wings, and the development into the adult form is accomplished gradually, without pupation.

In life and habits, however, termites are remarkably like ants. Both are social insects, and the social organization of the termites is even more complex than that of ants—indeed, it is the most highly developed system of social life found in the entire animal kingdom, outside of the human species. This fact proves that there is no necessary and direct relation between height of social organization and position in the zoological system.

About 350 species of termites have been distinguished and described. All of them live in societies, or states, but these differ very greatly in population and constitution. The members of a society vary in number from a few hundreds, in some species, to millions, and hundreds of millions, in others, but they are always divided into several castes, which can be clearly distinguished by their bodily appearance. In some cases the differences are so great that it seems impossible that the various castes can belong to the same species. The number of castes, also, differs greatly in different species.

In every species, however, there are two sharply distinguished general classes—the propagators and the workers. The former attend solely to the perpetuation of the species, while the workers, incapable of propagation, perform all the work of the society. The working class is subject to further differentiation, or specialization. Some of its members, which are called soldiers and are easily distinguished by the size and shape of their heads, are set apart for the defense of the state. Furthermore, both the soldiers and the true workers may be divided into several castes, which differ in size, form, and duties. For example, the large soldiers form an army for the defense of the commonwealth against external foes, while the small soldiers constitute a police force for the maintenance of internal order. So, too, the large workers attend to the collection of food and other outside labor, while the small workers take care of the king, queen, and young brood, keep the nest clean, etc.

* For a fuller account, see the author's forthcoming book: "Die Termiten oder 'weissen Ameisen.'" (Klinkhardt, Leipzig.)

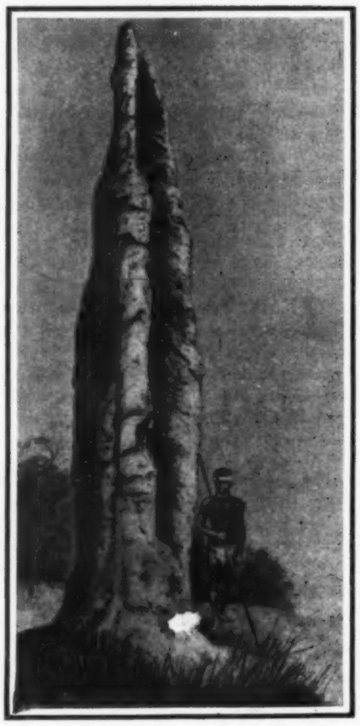


FIG. 2.—AN AUSTRALIAN TERMITE TOWER, 23 FEET HIGH.

FIG. 3.—A MUSHROOM-SHAPED TERMITE NEST (CAMEROON).

Nor are all the propagators alike. They include, first, young, long-winged individuals, which soon leave the nest to mate and found new colonies, and, secondly, an older pair, the king and queen, which have lost their wings and devoted their lives to increasing the population of the state. But if they are destroyed by any chance the state does not perish, for the citizens quickly adapt two of the young brood to the performance of the royal functions and the work of propagation goes merrily on. These substitutes, or regents, are easily distinguished from the original king aand queen, for they have never passed through the long-winged stage of development, but have been evolved directly out of short-winged adolescents, or nymphs. Strictly speaking they are not perfect insects, but nymphs with fully developed organs of reproduction.

To all these various classes of adult members of the community must be added a very numerous brood of offspring of all ages, from the tiny, newly hatched larva, entirely destitute of wings, to the nearly full grown, short-winged nymph.

Hence if we open the nest of a highly organized termite community we shall find therein: 1, the king and queen; 2, long-winged young adults (only at certain seasons but then in great numbers); 3, workers, large and small, forming the greater part of the population; 4, soldiers, large and small; 5, larvæ and nymphs.

The long-winged, dark-colored propagators bear little resemblance to the wingless, milk-white workers, and the resemblance is not increased after the former shed their wings, and become kings and queens. The older the queen becomes, indeed, the more strikingly does she differ from her subjects and even from her consort. As her fruitfulness increases her abdomen expands to twice, thrice, even to eight or nine times the length and thickness of the king's whole body. The contrast with the workers is vastly greater. An old queen may exceed in bulk twenty thousand workers! This enormous enlargement is made possible by the elasticity of the thin skin between the hard segments of the abdomen. This skin is colorless and transparent and the white muscles show through it, so that the queen resembles a white sausage, marked with a few brown streaks due to the segments (Figs. 1 and 6-b). Queens 4 inches long, with the abdomen occupying nine-tenths of the total length, have been found. These shapeless creatures, of course, can scarcely move, but they do not need to move, as their whole life is passed in the royal cell. In many species, however, the queen never attains such colossal dimensions. As a rule, the size of the queen is directly proportional to the size of the community.

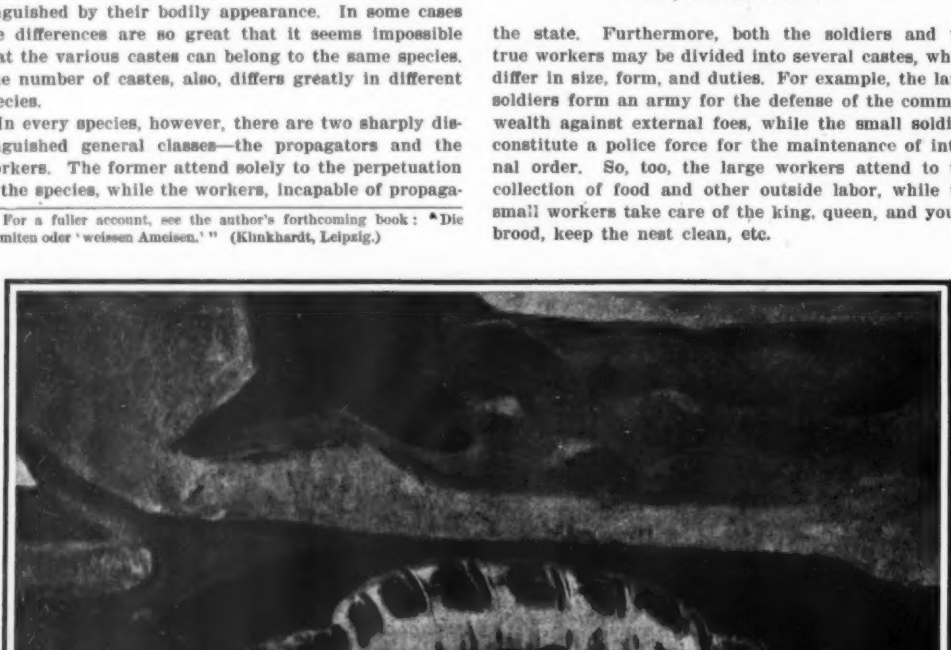


FIG. 1.—A TERMITE QUEEN AND HER COURT.

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The soldiers differ most conspicuously from the workers in the size and shape of the head. Some soldiers have oval or angular heads larger than the rest of their bodies (Fig. 6, *d*, *e*). Others have smaller heads ending in long, sharp snouts (Fig. 6, *g*), which they carry aloft in a very comical fashion. The function of this snout is not definitely known. It pours out a thick, slimy secretion when the insect is touched. The secretion may be a means of defense or, possibly, a material employed in building the nest. The function of the big-headed soldiers, on the other hand, is perfectly obvious, for their great jaws are formidable

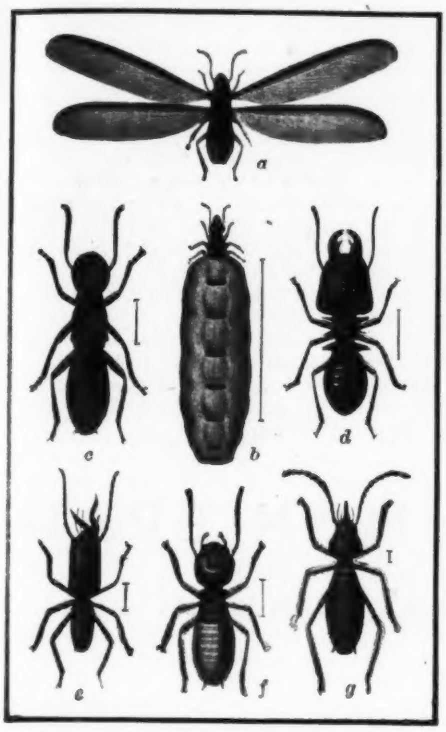

FIG. 6.—TERMITE CASTES.

a, Young female; *b*, queen; *c*, king; *d*, *e*, big-headed soldiers; *f*, worker; *g*, small-headed soldier. (Not drawn to the same scale.)

weapons, as I learned by experience in my first encounter with large termites, in Abyssinia. My hand, rashly thrust into the mass of insects, was quickly bleeding from dozens of deep wounds. When a nest is attacked, these soldiers rush forth and call their fellows by beating the ground with their heads, producing a rattling sound, which on one occasion put my native servant to flight.

The differences between the castes are due chiefly to arrested development. Only the true propagators are perfect insects. The workers and soldiers are larvæ (of both sexes) with atrophied sexual organs and otherwise adapted for the performance of special duties, and the substitute kings and queens may be regarded as larvæ with abnormally developed sexual organs.

The workers regulate the numbers of the several castes by killing and eating superfluous individuals in case of excess, and rearing recruits for the deficient castes, by methods which are yet unknown, although there is every reason to believe that the direction in which the young brood develops is influenced by modifying its diet. We know something of the development of substitute kings and queens. In all the other larvæ, when nearly full grown, the end of the intestine is packed tightly with parasites, which press on the sexual organs and check their development, but the larvæ which become substitutes are nearly or quite free from these parasites. It appears probable that the sexual development of the substitutes is promoted by the removal of the parasites by the administration of a cathartic or anthelmintic food.

The life of termites is passed almost entirely in darkness. Their nests are usually entirely closed above and the roads that diverge from them are either underground or covered with earth. On one day in their lives, the young long-winged perfect insects pour out of the nest by thousands, through one or more openings made for the purpose, rise in the air and scatter in all directions. Soon, however, they descend to the ground and, by breaking off their wings, doom themselves to remain there.

Then they search diligently for sites for new nests, usually hunting in pairs, the female leading. The site having been selected, digging is begun, either by the female alone, or by both, working back to back, until they have buried themselves for life. Thus they construct their bridal chamber—for they do not mate in the air, like ants, nor yet during the so-called "love walk" which leads them to their home. They do not become ripe for mating until after they have gone underground. This example of constancy and co-operation before marriage and even before puberty is unique in the animal kingdom.

Few of the countless thousands that leave the nest reach the harbor of matrimony. Most of them are devoured by ants, lizards, snakes, and birds, but the mother community possesses a source of new life, ever flowing to furnish the next annual swarm and to repair the losses caused by natural and violent death among the workers and soldiers. This source is in the great royal chamber which lies in the center of the nest, surrounded by smaller chambers filled with eggs and young larvæ.

Few persons have enjoyed the privilege of peeping into this sanctum and observing the mysteries there performed in darkness. I once succeeded in extracting the royal chamber from a nest of the African warlike termite, and examining it through an incision just large enough to admit sufficient light to make the interior visible, without disturbing the inmates. I beheld a very animated and interesting scene. In the background lay the enormous white queen, three inches long and so thick that she was pressed tightly between the floor and ceiling. She was motionless, except for a series of waves moving rearward along her swollen abdomen. By her side stood the king, a dwarf compared with his mate, in a very remarkable posture, with his long legs widely separated, his head down and his tail cocked upward. Now and then he pressed against his consort's side or tried to crawl under her. The royal pair was surrounded by hundreds of small workers, some running around as if in a circus, others reaching out from floor and ceiling to brush and lick the queen and king. The queen's head, thorax and legs were covered with little workers, busily grooming, caressing, and feeding her. At the opposite end of her body the scene was still livelier. At intervals of from one to three seconds a tiny, long-oval egg issued from the tip of the abdomen and was immediately seized by a worker, cleaned and carried away to one of the surrounding egg chambers. These operations were performed with a regularity that suggested the work of a factory. When we consider that a termite queen probably lives ten years or longer and devotes at least half her life to egg laying, we can form some idea of her prodigious fertility and of the number of her subjects. The necessity for the constant presence of the king also becomes apparent. The single fertilization practised by ants and bees would not suffice for so multitudinous a progeny, but the queen's seminal reservoir must be frequently replenished.

The royal pair was attended by police and guards, as well as by servants. Small soldiers moved about among the workers, occasionally striking laggards with their heads, and a few large soldiers were posted in a ring surrounding the rest of the company, with their great heads and formidable cutting jaws directed outward, evidently for the purpose of repelling intruders. The entrances to the royal chamber were too small to allow the passage of the royal pair, which was thus imprisoned for life.

This picture, of course, cannot be assumed to be a

FIG. 7.—A "MUSHROOM CAKE."

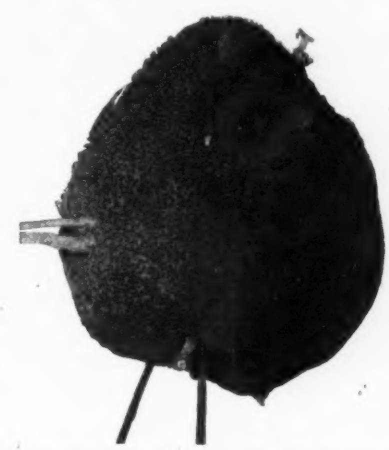

FIG. 8.—A TERMITE NEST BUILT IN A TREE, WITH PART OF THE OUTER SHELL REMOVED.

true representation of any species except the warlike termite, but there is no reason to believe that it does not represent, fairly well, the life of all numerous colonies with colossal queens and special royal chambers. In species which have small colonies, small queens, and no special royal cells, the work of propagation is doubtless carried on far more simply.

The structures reared by termites represent the highest achievement of animal architecture and often profoundly modify the appearance of the landscape. Australian termites build groups of great hills that resemble native villages (Fig. 4). Termite architecture is not restricted to one system. Style, material, construction, and the character of the site vary with the species, and are also modified by circumstances. The material is earth, wood, or both, finely divided and mixed with intestinal secretions. The raw materials are always swallowed, but in some species they go only as far as the crop, to be mixed and ground, and are then regurgitated, while in other species they traverse the entire intestinal canal and are deposited, as excrements, where they are required for building. In some cases they pass through the crop of a second individual before they are used. The intestinal secretions form a cement which gives the walls astonishing hardness and resistance to the weather. Many nests cannot be opened without using gunpowder or dyna-

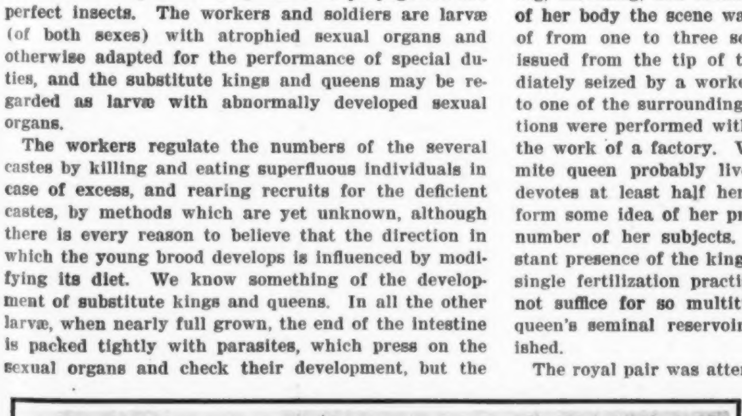

FIG. 4.—A TERMITE VILLAGE IN AUSTRALIA.

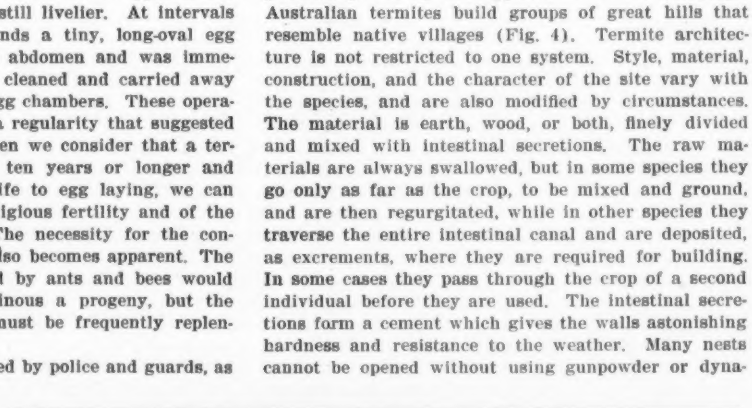

FIG. 5.—A TERMITE HILL OPENED, SHOWING "MUSHROOM CAKES."

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mite. As a rule, the nest is entirely closed, and thus protects the insects from their numerous enemies, which include cold and dryness, for termites cannot live in a dry atmosphere.

The general arrangement of the interior is the same in nearly all nests. In the center is the royal chamber, inclosed with very thick and hard walls. This is surrounded by a series of concentric shells. The first shell contains numerous small cells filled with eggs and larvæ, the second and thickest shell is divided into large compartments for the workers and soldiers, the third shell contains small compartments, and the fourth is undivided and forms the outer wall which completely incloses the nest. This typical construction is found in many nests, especially those which are built in trees and entirely of wood pulp (Fig. 8). In hill nests the outer shells do not completely inclose the nucleus but are in the form of domes. In some nests the number of shells is reduced to three, two, or even one.

The warlike termite (*Termes bellicosus*) of Africa builds a conical hill which sometimes attains a height of 6 to 10 feet and a circumference of 23 to 33 feet. Many hill nests are surmounted by ventilating towers or chimneys. These are intermediate forms between the hill nests and the tower nests, which have almost vertical walls, and include the largest structures built by termites or other animals. The towers of some Australian termites are about 23 feet high, very slender and stiffened with pilasters (Fig. 2). The "compass" nests of Australia are oblong and are always set with their ends to the north and south. Some of them are 10 to 13 feet high and 6 to 10 feet long, and they are often found in large groups which resemble villages.

Lastly, there are the mushroom-shaped hills of Cameroon (Fig. 3). These are only 20 or 30 inches high, and are found in groups of five or six. Probably the hills of each group are connected by underground passages and occupied by a single community.

Not all termites, however, are great builders. Termite architecture, like other arts, has been gradually developed, and some still living species are beginners and bunglers, able only to excavate irregular labyrinths in the earth or in decayed wood.

As termites shun the light and air, they are compelled to construct tunnels or covered roads from their nests to their feeding grounds. These galleries are often thousands of feet in length and are continued along house walls and tree trunks. Trees, beams, and telegraph poles are often found covered with a crust of earth, applied at night with amazing celerity, beneath which the termites carry on their destructive foraging in security.

The food of termites consists chiefly of vegetable substances, especially wood, which, as it contains little nitrogen, must be consumed in large quantities. Many species, however, have learned to dispense with this wholesale consumption of wood by employing fungi to extract its nitrogenous part and supply them with concentrated food. For this purpose spongy, yellowish "mushroom cakes" (Fig. 7), varying in size from that of a hazel nut to that of an infant's head, are formed of wood pulp and placed in the large apartments of the workers. These cakes are usually found covered with white globules, as big as a pin's head, which appear to be fungous growths of a peculiar kind, developed by termite cultivation, and which are used as food, especially for the larvæ. When a portion of the cake becomes exhausted, it is removed and replaced by fresh wood pulp.

The termites, by their numbers and social co-operation, form a mighty power in the animal kingdom, and other species, especially of insects, have found it advantageous to form alliances with them, and to live in their strong and capacious dwellings for the sake of shelter, food, care or the elevated temperature required for hatching eggs. Most termite nests harbor various beetles, flies, caterpillars, and other insects, many of which have become so greatly changed by long continued symbiosis that it is almost impossible to recognize their true nature. The characteristic and universal alteration, and the cause of all the rest, is an enormous distension of the abdomen. This is probably caused by termite diet, especially the royal food, with which the foreign guests appear to be regaled. The termites do not appear to derive any benefit from their guests, most of which seem to have been, originally, marauders seeking the young brood. At all events, the guests do not serve as "cows," like the aphides kept by ants. Such "cows" have been found in termite nests, but very rarely.

Our knowledge of termites is still very meager. We know nothing of their psychology, on which the whole structure of their social life is necessarily based. A practical experimental method of studying that psychology would open a field of surpassing interest.—Translated for the Scientific American Supplement from Illustrirte Zeitung.

THE MECHANISM OF THE HUMAN BRAIN.

THE LAWS THAT GOVERN PSYCHIC PHENOMENA.

BY DR. ROBERT FUERSTENAU.

The law of cause and effect governs the mechanism of the brain as it governs that of the body and all other mechanisms and operations. In recent years a number of psychical phenomena and processes have been studied and found to be regulated by inexorable law. It is impossible to observe directly the processes that go on in the brain cells, but we can study the reflex bodily movements which are evoked by various external stimuli through the intermediation of those processes. The whole chain of events is called a psychophysical process or phenomenon.

A well-known example is the contraction of the pupil of the eye which immediately follows sudden exposure to intense light. The contraction is produced by a process in the brain which, in turn, is inaugurated by nervous impulses caused by the stimulation of the optic nerve by the unaccustomed light. The character of the reflex is the same in all persons, but its intensity varies. The extent of the contraction is measured with an apparatus called a pupilometer. This consists essentially of a telescope with a micrometer eyepiece, combined with a device by which the light of an electric lamp can be suddenly flashed into the eye. The observer first measures the pupil of the subject's eye in faint illumination by setting the two parallel and movable threads of the micrometer tangent to the image of the pupil, on opposite sides. Then the electric light is flashed into the eye, the threads are moved toward each other until they again graze the image of the contracted pupil, and the distance through which they moved is read on the scale.

In this way it has been found that the contraction of the pupil is much less in insane than in normal persons. Still more striking differences between the sane and the insane appear in the case of another reflex, the knee jerk.

When one thigh of a seated person is placed on a raised support so that the leg swings freely and the foot does not touch the floor, a smart blow applied to a certain part of the knee is followed by an involuntary and more or less violent kick, or forward and upward movement of the leg and foot. For the purpose of exact investigation the leg is inclosed in a tube attached to a cord which passes over a pulley and is kept taut by weights attached to its free end. Every movement of the leg is recorded on a rotating vertical smoked cylinder by a stylus which is connected with the cord by a lever.

The curve thus drawn by the knee jerk of a normal person consists of a sudden elevation, followed by a more gradual and very much smaller depression and, finally, a still smaller elevation above the horizontal line which the stylus, when at rest, draws on the rotating cylinder. If the subject is not mentally sound, the curve consists of a considerable number of elevations and depressions, gradually decreasing in amplitude. In other words, the vibrations of the pendent leg, which is free to oscillate like a pendulum, are rapidly damped or destroyed in the normal subject by a sort of physiological brake. In insane persons this brake acts imperfectly or not at all. Furthermore, various mental diseases give characteristic curves, so that this simple experiment is a valuable aid in diagnosis.

Prof. Sommer, the director of the clinic for mental and nervous diseases in Giessen, who has employed this method with great success, has also investigated another class of bodily movements which are intimately dependent on mental states. These are the involuntary movements of expression of emotions, which can be observed in every part of the body and which have been carefully studied and measured with the aid of ingenious apparatus.

A well-known example is the involuntary contraction of the muscles of the forehead which causes frowning and wrinkling of the brow. These movements take place in one plane, and are therefore easily registered. The recording of the involuntary movements of the legs, arms, and hands, which are made in all directions, is far more difficult.

By connecting two points of the human skin with the electrodes of a sensitive galvanometer it is often possible to detect the existence of an electric current, the strength of which varies with the nature and degree of the mental occupation (calculation, deep meditation, fright, etc.). This part of the subject, however, is still veiled in mystery.

Speech affords still another means of investigating psycho-physical reactions, by means of what are known as association experiments. The subject is seated before a number of keys, by pressing which various words, printed on cards, can be successively exposed to view. The subject is requested to pronounce, as soon as possible, the first related word which the printed word suggests to him. As he utters the word the sound waves of his voice, acting upon a thin membrane which carries a metallic point, break an electric contact and thus stop a chronoscope which has been started by the depression of the key. The interval between stimulus and reaction, measured in this way, is never less than one second. Usually it is a few seconds, but it is very much longer under certain conditions, especially if the subject is mentally unsound.

For example, a man who had attempted suicide by drowning, gave appropriate responses to a number of words after intervals varying from 1.2 to 1.8 seconds, but required about 5 seconds to pronounce words suggested by the following printed words: sea, water, ship, swim. This very interesting result may be explained by supposing that in the mind of this man who had recently sought a watery grave all ideas associated with that of water were in so confused a state that time was required for their exact expression in words.

Much shorter intervals of time must be measured in experiments on the time required for an impression made on the eye, ear, or other organ of sense to reach the brain, or for a motor impulse to travel from the brain to an organ or limb. These intervals are measured by means of a chronoscope sensitive to thousandths of a second.—Reclams Universum.

A $500 PRIZE FOR A SIMPLE EXPLANATION OF THE FOURTH DIMENSION.

A friend of the Scientific American, who desires to remain unknown, has paid into the hands of the publishers the sum of $500, which is to be awarded as a prize for the best popular explanation of the Fourth Dimension, the object being to set forth in an essay the meaning of the term so that the ordinary lay reader can understand it.

Competitors for the prize must comply with the following conditions:

1. No essay must be longer than 2,500 words.
2. The essays must be written as simply, lucidly, and non-technically as possible.
3. Each essay must be typewritten and identified with a pseudonym. The essay must be inclosed in a plain sealed envelope, bearing only the pseudonym. With the essay should be sent a second plain sealed envelope, also labeled with the pseudonym, and containing the name and address of the competitor. Both these envelopes should be sent to "Fourth Dimension Editor, Scientific American, 361 Broadway, New York, N. Y."
4. All essays must be in the office of the Scientific American by April 1, 1909.
5. The Editor of the Scientific American will retain the small sealed envelope containing the address of the competitor and forward the essays to the Judges, who will select the prize-winning essay.
6. As soon as the Judges have agreed upon the winning essay, they will notify the Editor, who will open the envelope bearing the proper pseudonym and containing the competitor's true name. The competitor will be notified by the Editor that he has won the prize, and his essay will be published in the Scientific American.
7. The Editor reserves the right to publish in the columns of the Scientific American or the Scientific American Supplement three or four of the more meritorious essays, which in the opinion of the judges are worthy of honorable mention.

Prof. Henry B. Manning, of Brown University, and Prof. S. A. Mitchell, of Columbia University, will be the judges.

THE PRODUCTION OF OZONE.

THE EFFECT OF HEAT.

BY ARTHUR W. EWELL.

FRANZ FISCHER, of Berlin, has recently demonstrated that ozone is produced when oxygen is raised to a high temperature. His methods have not as yet reached the high efficiency obtained by other processes, but the work is very promising. Fischer has shown his own belief in the ultimate success of thermal production by securing a broad patent covering such processes, and this patent has apparently been transferred to the Allgemeine Elektricitäts Gesellschaft.[1]

The subject is particularly interesting to students of physical chemistry, because it illustrates the frequent ultimate technical value of experimental and mathematical investigations, which, by themselves, appear only of theoretical importance.

Some five years ago, at a scientific gathering at Cassel, Nernst announced that the equilibrium concentration of ozone increased with the temperature and that he had calculated the normal concentration to be as follows:

Temperature centigrade	1910	2957	6367
Concentration of ozone (per cent)	0.1	1	10

That is, for every 1,000 grammes of oxygen at 1910 degrees, there will normally be one gramme of ozone.

It is not difficult to see how these figures were obtained. Suppose a mass of oxygen is allowed to remain under constant conditions a sufficient time for the equilibrium amount to be transformed into ozone. Let us calculate the difference of potential between the ozone and the oxygen, for, in general, two dissimilar bodies, in contact and in equilibrium, will be at different electrical potentials. Berthelot[3] found that 29,600 calories were required to form one gramme-molecule of ozone from oxygen. If this potential energy were completely transformed into electrical energy we should have

$$4.19 \times 29{,}600 = 2 \times 96{,}500 \times E$$

where $2 \times 96{,}500$ is the quantity of electricity associated with one gramme-molecule, 4.19 is the factor to change calories to joules, and E is the above natural difference of potential. Solving, we find E is 0.64 volt.

Grafenberg[4] and Luther[5] have measured the difference of potential between a platinum electrode which has absorbed ozone and one which contained hydrogen, and also the minimum potential required to liberate ozone in electrolysis. After allowing for the difference of potential of the hydrogen electrode, their results agree quite closely with 0.64.

If we regard this natural difference of potential as due to the difference in concentrations of the ions in oxygen and ozone, we may employ Nernst's concentration equation:

$$E = \frac{R\,T}{e}\,ln\,\frac{c_1}{c_2}$$

where R is the gas constant, 1.98 joules, T is the absolute temperature, e is the charge associated with one gramme-molecule, c_1 is the concentration in the oxygen, and c_2 is the concentration in the ozone.

We will assume further that the heat of formation of ozone varies little with the temperature, i. e., that E is constant, and that the concentration of the ions in the two gases is proportional to the concentration of the gases. Hence, changing to common logarithms, we have:

$$0.64 = \frac{1.98 \times 2.30}{2 \times 96{,}500}\,T \log \frac{c_1}{c_2}$$

If we substitute $c_1/c_2 = 100$, T comes out 3,230, or 2,957 deg. C., and the two other results in the above table are similarly obtained. (If the equations above are examined, it will be noticed that the charge, which is assumed as two faradays, cancels out. Great importance should not, however, be given the results in the above table, on account of possible inaccuracy in Berthelot's work and uncertainty regarding the hydrogen electrode.)

Dr. Clement[6], working under Nernst, attempted to obtain ozone by heating oxygen to high temperatures. He obtained a gas which set free iodine and which shows other resemblances to ozone, but upon testing with tetrabase paper[7] he always obtained the yellow color characteristic of oxides of nitrogen, and never the violet color which characterizes ozone.

Nernst attributed his failure, not to incorrect theory, but to insufficient rapidity of cooling. If the mixture of ozone and oxygen, which is stable at a high temperature, is cooled suddenly to a low temperature, it remains at practically the same composition. For, although at ordinary temperatures the equilibrium concentration of ozone is almost infinitesimal, yet the decomposition toward this concentration is exceedingly slow compared with the rapidity with which the equilibrium concentration is reached at higher temperatures. If the ozone and oxygen are not removed almost instantaneously from the high temperature region, the product obtained will correspond to a comparatively low temperature, and the content of ozone will be inappreciable.

The equilibrium between ozone and oxygen subjected to the silent discharge is totally different. Warburg[8] has shown that here the equilibrium concentration of ozone increases with decrease of temperature. Briner and Durand[9] obtained pure ozone by means of the silent discharge at the temperature of liquid air.

It is unfortunate that we cannot analyze the gas at high temperatures. The change of volume corresponding to the formation of ozone is too small to measure accurately. Warburg's beautiful work upon absorption spectra suggests that possibly some information might be obtained by this means.[10]

Franz Fischer repeated Clement's work in the chemical laboratory of the University of Berlin, with such modification as would give a greater velocity of cooling.[11] He tried first various flames (hydrogen, acetylene, etc.) over liquid air or oxygen. Ozone was always found dissolved in the liquid, and with liquid air solid crystals of oxides of nitrogen were also formed. Next platinum was maintained at incandescence in liquid air or oxygen, and traces of ozone were found, although the experiments were somewhat unsatisfactory on account of the rapid destruction of the platinum.

An electric arc was maintained in liquid air and ozone was found, either dissolved or as dark blue globules. Finally, a Nernst glower was heated to normal brilliancy in liquid air or oxygen and a large amount of ozone was obtained.

The expense and inconvenience of using liquid air or oxygen led Fischer to seek a more practical method.[12] Clement's experiments, where oxygen traversed incandescent bodies, were repeated with far higher velocities. The maximum velocity used by Clement was 1 meter per second. Fischer worked up to 90 meters per second. The air or oxygen emerged from a slit a few tenths of a millimeter wide and impinged upon a Nernst glower a few millimeters from the slit. The heated gases then entered a glass tube surrounded by cold water.

When the velocity was less than 5 meters per second, no ozone was formed, but a large amount of oxides of nitrogen was produced. As the gas velocity was increased, an increasing yield of ozone was obtained, at 7 meters per second the ozone began to predominate, and at 30 meters per second no nitrogen oxide could be detected. Therefore, both the formation and the decomposition of ozone are more rapid than that of oxides of nitrogen. If the velocity was too great, e. g., 76 meters per second for a 0.1 millimeter slit, the ozone has insufficient time to reach the equilibrium concentration, and the yield decreases.

The highest concentration and the greatest efficiency were obtained with a velocity of 57 meters per second (1 millimeter slit) and the highest feasible temperature, 1,930 deg. C. Under these conditions 3.60 milligrammes of ozone were produced in 160 seconds in 10 liters of air. The concentration was, therefore, 0.029 per cent by weight, or 0.126 per cent of the atmospheric oxygen. The Nernst glower required 0.50 ampere at 123.5 volts. The commercial efficiency, or the yield in grammes per kilowatt-hour, was, therefore,

$$\frac{0.0036 \times 3{,}600 \times 1{,}000}{0.5 \times 123.5 \times 160} = 1.3.$$

If, instead of air, 92 per cent oxygen were used, the percentage of oxygen changed to ozone was much less, under similar conditions, but the commercial efficiency was a little higher. In the earlier experiments, where the cooling was accelerated by the use of liquid air, a commercial efficiency of 3.5 grammes of ozone per kilowatt-hour was obtained for a concentration of 0.12 per cent and 2 grammes for a 1 per cent concentration.

Let us compare these yields with those obtained by the silent discharge at ordinary temperatures[13] and by electrolysis.[14]

YIELD IN GRAMMES PER KILOWATT-HOUR.

Concentration (gr. per cu. m.)	Thermal (blast)	Thermal (liq. air)	Electrolysis	Points +	Points —	Dielectric
0.37	1.3	...	..	60	40	70
1.8	...	3.5	..	50	37	55
14.	...	2.	..	..	10	..
290.	...	...	70	..	..	..

Therefore, at present the thermal production of ozone is relatively inefficient, but when it has received as much attention as has been devoted to the other methods, great improvements may be expected.

Many of the above phenomena may easily be shown in a lecture room. Remove the outer casing from a single glower Nernst lamp. Procure a seamless brass tube about 6 millimeters internal diameter and 1 centimeter external diameter, crush one end together and file away until there is a straight slit about 0.1 millimeter wide and 1 centimeter long. File away one side almost to the slit, so that it can be brought close to one of the heating tubes, and about 2 millimeters from the glower. By means of an ordinary foot bellows drive a current of air through the slit upon the incandescent glower. The odor of ozone or oxides of nitrogen will soon be evident, and may be demonstrated to a class by holding in front of the blast and as close as possible to the glower, a paper saturated with starch iodine solution. The characteristic blue color will soon appear.

Since the yield of ozone decreases greatly with increase of moisture,[15] it will be of advantage to dry the air between the bellows and the slit by passage through calcium chloride tubes. A tube filled with glass wool next the slit prevents clogging by foreign particles. If a manometer is inserted, next the slit, the velocity of the air may be calculated from the formula $v = \sqrt{2p/d}$, where p is the pressure in dynes per square centimeter, and d is the density.

An organic chemist can readily prepare tetramethyl-p-p'-diamino-diphenylmethane (tetrabase). A paper soaked with an alcoholic solution, held in the blast close to the glower, will turn yellow at low velocities, and at high velocities a bluish violet, the former signifying oxides of nitrogen and the latter ozone. The starch iodine paper turns blue with both.

If the drying tubes are replaced by a gas washing bottle containing water, the tetrabase paper will not be affected, showing the absence of ozone and oxides of nitrogen. Starch iodine paper will be colored to practically the same degree as before, because hydrogen peroxide is now produced in considerable amount.[16]—Electrochemical and Metallurgical Industry.

A short time ago a leading physician strongly advocated the preservation of milk at a low temperature in order to secure the destruction of the bacteria present. That such a system is fallacious actual scientific investigation has conclusively proved. A small quantity of ordinary clean milk as taken from the dairy was immersed in a refrigerator and reduced to freezing-point. In the course of five or six weeks the milk was found to be teeming with millions of bacteria in a healthy and flourishing condition. This multiplication occurred despite the fact that the milk was in a semi-solid state of ice-crystals, and when a portion was raised to normal temperature no evidence of contamination was apparent to either the smell or palate, while when boiled it did not curdle. This result is quite in harmony with the theories of science concerning the non-influence of intense cold upon the propagation of bacteria. In regard to the liquefaction of gases, it has been found that, notwithstanding the intense degree of cold attained, it exercises no militant effect upon these organisms. It is for this reason that the recent liquefaction of helium, which it is hoped will give us absolute zero, is of far-reaching interest. It is anticipated that the temperature will be so low as to be incapable of supporting life of any sort. Incidentally, however, it may be pointed out concerning the foregoing experiments with frozen milk that although it may taste sweet it does not follow that it is free from bacteria.

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GLASS BRICK: A NEW BUILDING MATERIAL.

HOW IT IS MADE AND EMPLOYED.

Two YEARS ago Mr. C. B. Lawton of Pittsburg conceived the idea of a practical glass brick, and made a solid or block mold from which a lead brick was cast as a model. Upon the completion of the mold eleven glass brick were made. The mold was then shattered by the influence of the heat and hammering necessary to start the formed brick from its position in the mold. These bricks cost the inventor about $20 each. The experiment proved, however, that he was on the right track but with the wrong process. Later experiments extending over two years resulted in the building of a factory at Connellsville, Pa., and the forming of a company. The process of manufacture now in use is briefly as follows:

The mold is made of special mixed cast iron weighing in all about 125 pounds. The sides and ends of the brick are formed by four separate parts of the mold, opening outward on hinges so as to allow the parts forming the indented ends to be withdrawn from the hot glass—the top of the brick being formed by a separate part or ring easily detachable from the mold proper, through which, when in position, the glass is poured from a ladle. A plunger, similar in shape to the inside of the brick, enters and passes through the ring to the bottom of the mold, forcing the molten glass to the corners, but leaving a thin sheet of glass on the bottom, which is afterward knocked out by the stroke of a special hammer.

These bricks were first made by the use of a common glass-house side-lever press, but this was found to be too slow to permit the making of bricks at a price within reach of the market. A special press has been designed holding five molds, by which the movements of each mold will be sufficiently rapid to make four bricks per minute with a total of six men at each press.

The hot bricks, immediately after being formed, are laid in uniform rows on a sheet-iron pan and are drawn through a 75-foot lehr with gas burners so arranged as to permit the cooling down of the hot brick slowly. The time consumed in the making of a complete brick from the melting tank to the lehr is two minutes; the time in the lehr is eight hours.

The surface is equal to, and exceeds in beauty, finished enamel bricks. The surface is imperishable except by violence. The cracking and crazing incidental to enamel bricks are entirely absent. Any color of which glass is capable can be produced in glass bricks.

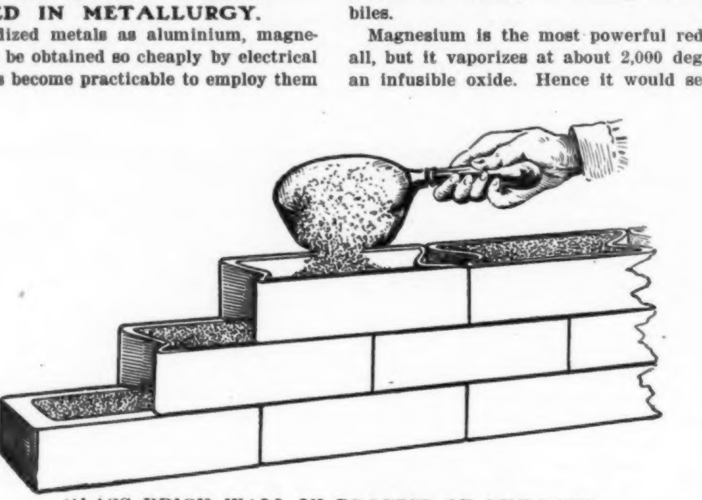
In construction, glass bricks can be laid up more rapidly than enamel bricks and with but a slight mortar joint, where required, producing nearly an entire glass surface.

Glass brick is the outline of a brick with indented ends, the center being entirely open. In construction the center is filled with concrete. Thus a wall will be glass upon the outside and concrete within. Tests have proved that cement adheres to glass. A wall built in this manner becomes like one solid sheet of glass and concrete and will prevent the opening of a joint because of settling as is the case in ordinary brick or stone construction.

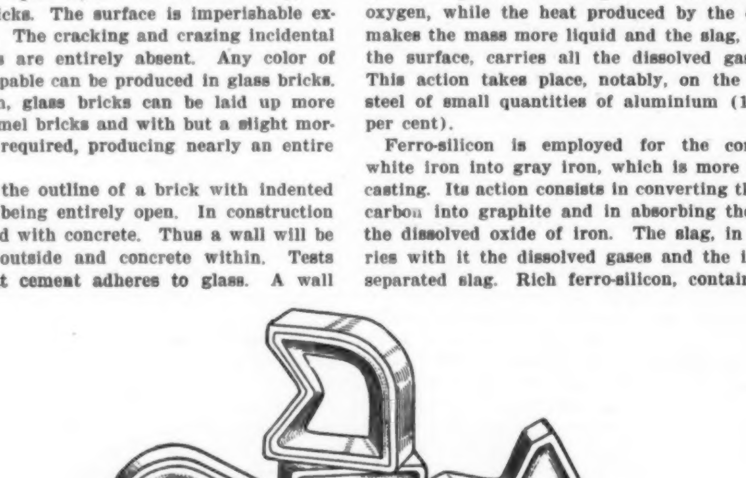
A glass brick wall is proof against the passing of water. At the works of the company is a large experimental tank which holds 1,000 barrels of water. When completed the tank was found to be proof against the passing of water. This tank is now used for water supply and for fire purposes.

Glass bricks are readily laid up with a butted joint without concrete filling, leaving a dead air chamber. This, it is claimed, fills a large demand where dampness is to be figured with or sweating walls are to be avoided.

Partitions built of this brick need no center support as the combination of glass brick with concrete filling makes a truss capable of holding its own weight and tenfold more, if necessary.



GLASS BRICK WALL IN PROCESS OF BUILDING. CONCRETE FILLING.



OUTLINE SHAPES OF GLASS BRICKS.

The lower center is a standard shape, the others are terminals.

THE NEW REDUCING AGENTS EMPLOYED IN METALLURGY.

SUCH easily oxidized metals as aluminium, magnesium, etc., can now be obtained so cheaply by electrical methods that it has become practicable to employ them for the reduction of the oxides of iron, copper, etc., both in smelting and in the foundry. In both cases the principal difficulty is to avoid the retention in the product of too much of the reducing metal, as this must be added in excess in order to insure complete deoxidation.

In foundry work the employment of these metallic reducers has the further advantage of eliminating the bubbles of nitrogen, hydrogen, oxygen, and other gases which give rise to holes injurious to the strength of the casting. The reducing metal combines with the oxygen, while the heat produced by the combination makes the mass more liquid and the slag, in rising to the surface, carries all the dissolved gases with it. This action takes place, notably, on the addition to steel of small quantities of aluminium (1/50 to 1/20 per cent).

Ferro-silicon is employed for the conversion of white iron into gray iron, which is more suitable for casting. Its action consists in converting the combined carbon into graphite and in absorbing the oxygen of the dissolved oxide of iron. The slag, in rising, carries with it the dissolved gases and the incompletely separated slag. Rich ferro-silicon, containing 75 per cent of silicon and very little carbon, is the most efficacious. In France alone 40,000 horse-power is employed in producing ferro-silicon in the electric furnace, one horse-power producing more than one-quarter pound of 50 per cent ferro-silicon per hour.

Calcium is a more powerful reducing agent than aluminium. It possesses the great advantage of combining with hydrogen, sulphur, and nitrogen, but also the disadvantages of vaporizing below 2,400 deg. F. and forming an infusible oxide, which prevents its employment in smelting. As pure calcium causes too violent a reaction, alloys of calcium, aluminium, and silicon are recommended for foundry work. Calcium may be employed in smelting by mixing it with aluminium or silicon. The absorption of oxygen in the furnace produces calcium aluminate or silicate, either of which is more fusible than alumina or lime. The effect of calcium on the mechanical qualities of castings is very beneficial. The calcium process is cheap and has a great future before it. It is already employed in Germany in making castings for automobiles.

Magnesium is the most powerful reducing agent of all, but it vaporizes at about 2,000 deg. F. and forms an infusible oxide. Hence it would seem to be inadmissible in the metallurgy of iron, although the breaking strength of steel is increased 40 per cent by the addition of 1/20 per cent of magnesium.

Vanadium is a very powerful reducing agent. It combines with nitrogen and gives steel and cast iron great resistance to tearing and to repeated and alternating stresses, as well as a high limit of elasticity. It may be used in the form of ferro-vanadium, which should be as free from carbon as possible, as vanadium carbide makes steel brittle. It is employed extensively in the United States for locomotive castings. The ferro-vanadium is added after the steel has been partially refined by means of cheaper reducing agents and immediately before casting, yet only 1/10 of it, or not more than 0.6 per cent of the weight of steel, remains in the casting, the remainder separating as slag. The process is therefore expensive, the castings costing twice the price of ordinary steel. Ferro-vanadium containing 25 per cent of vanadium is usually employed.

It has been found that a "burned" iron casting can be restored and doubled in strength by the addition of 1/20 per cent of vanadium, which also increases the power of the metal to withstand vibration. Hence ferro-vanadium is employed in cast-iron machine frames and wagon wheels. An alloy containing 15 per cent of vanadium and 6 per cent of carbon is employed.

REACTION PROPELLERS FOR AEROPLANES.

R. LORIN suggests the employment of reaction propellers for aeroplanes, for the following reasons: The screw propeller is excellent for moderate speeds, but its tractive effort diminishes when the velocity exceeds 100 or 125 feet per second. Furthermore, the efficiency of the screw propeller is only about 50 per cent, and as the maximum efficiency of the ordinary motor is only 20 per cent, the efficiency of the motor propeller system is only 10 per cent. The 50 per cent loss in mechanical transmission would be saved by the employment of a direct-acting reaction motor-propeller.

The apparatus would consist of a number of single-acting explosion cylinders, with their escape valves connected with funnels in which the escaping gases could gradually expand. This system is adapted to low pressures and could therefore be made very light, and the heating effect would be so small that cooling by water would not be necessary. With an explosive pressure of seven or eight atmospheres it is calculated that the system might be made both lighter and more powerful than a motor of the usual type. At low speeds both the thermal efficiency and the tractive effort would be less than those of the motor and screw, but at high speeds the proposed system would be very much more efficient than the ordinary system. Both horizontal and vertical steering could be accomplished by varying the direction of the axes of the cylinders.

RECENT PROGRESS WITH THE X-RAYS.*

SOME NEW DISCOVERIES.

BY G. W. C. KAYE, B.A., D.SC.

The past year or two has seen a considerable addition to our knowledge of the Röntgen rays and their associated phenomena. Prof. Röntgen discovered in 1895 that when cathode rays impinge on solid obstacles the now famous rays which bear his name are generated. Their remarkable penetrating powers created a sensation in the scientific world, imagination was given loose play, and almost everyone of the many workers who sprang up on all sides prepared to assist in the genesis of the "new physics" had his own conception of the nature of the rays.

Röntgen at first considered the rays to be longitudinal vibrations in the ether; Jaumann modified this conception and added a transverse component; Goldhammer and others preferred to regard the new rays as extremely short transverse vibrations akin to light waves; Stokes, in 1897, put forward a theory of irregular pulses in the ether; Michelson suggested their identity with ether vortices. Lastly many physicists, including Röntgen himself, were at one time inclined to the view that the rays are flights of material particles differing only from cathode rays in the absence of an electric charge. One by one most of these theories were abandoned as experiment yielded discriminating results, until at the present time we are left with the ether-pulse theory of Stokes, which, modified and elaborated by Sir J. J. Thomson, has received almost universal acceptance, and the "neutral pair" theory to which Prof. Bragg has recently given his support.

It was soon found by many workers (Röntgen, Campbell-Swinton, Ròiti, Kaufmann, Sir Oliver Lodge, and S. P. Thompson among others) that the heavier metals make the most efficient targets or anticathodes for the cathode rays to impinge upon in a Röntgen ray tube. Platinum has been generally used for the purpose; at any rate, for the better class of tubes. Recently thorium, iridium, tungsten, and tantalum have been employed with entirely satisfactory results. Their high melting points give them an advantage in these days of focus bulbs. (Pt 1,750 degrees; Ir 2,250 degrees; W 3,080 degrees; Ta 2,910 degrees C.)

Kaye (1908) has examined the behavior of some twenty elements when used as anticathodes in a discharge tube. He has shown that the intensity or quantity of the harder or more penetrating rays is very approximately proportional to the atomic weight of the element, the conditions, of course, being the same throughout. Fig. 1 illustrates the relation graphically over a region extending from carbon to bismuth. As to the quality or penetrating powers of the rays from the different elements there is little to choose between them.

This simple atomic weight relation between intensity and atomic weight does not hold when we are dealing with the softest X-rays. The metals of the chromium-zinc group (i.e., Cr, Mn, Fe, Ni, Co, Cu, and Zn) emit radiations very rich in soft rays, and, if only on the score of expense, may well be employed in many cases, as, indeed, some of them are in the cheaper tubes, with or without a thin coating of platinum. Most of these metals have, too, the advantage of high melting points (e.g., Cr 1,490 degrees; Mn 1,200 degrees; Fe 1,500 degrees; Ni 1,430 degrees; Co 1,460 degrees; Cu 1,084 degrees C.).

It is interesting to note that, contrary to what was formerly believed, the rays from a focus bulb are not uniformly distributed. The region of maximum intensity is situated at about 60 degrees from the normal to the anticathode, in a plane containing the normal and the incident beam of cathode rays. In this plane the intensity falls off, roughly speaking, by a cosine law.

The chief defect of the induction coil from the point of view of the X-rays worker is that it does not give pure unidirectional current; the harmful reverse currents at "make" can, however, be suppressed in the Röntgen tube by joining it in series with one or more rectifiers or valve-tubes. Of these there is a number on the market: that first introduced by Villard and since modified by Sir Oliver Lodge consists of an exhausted tube with a large spiral cathode and a small narrowly-inclosed anode.

To Villard also we are indebted for the "osmo-regulator," a device nowadays almost always employed to meet the "hardening" or lowering of the pressure which accompanies the continued running of a discharge tube. The regulator consists of a small platinum tube, sealed into the X-ray bulb, and closed at its outer end; its inner open end is in communication with the interior of the bulb. On applying a small flame to the extremity of the platinum tube, hydrogen diffuses into the bulb, and thus the degree of vacuum can be regulated to a nicety.

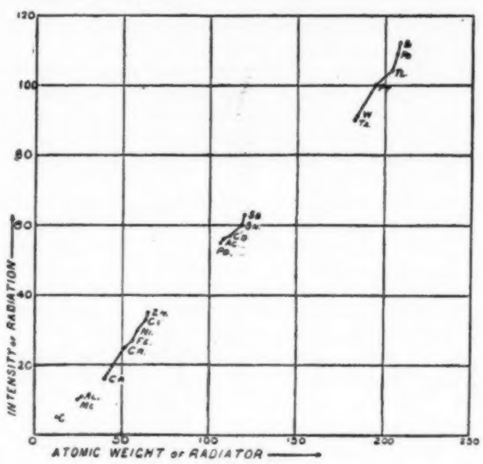


FIG. 1.

The vibrating hammer interrupter fitted to induction coils has, owing to the demand for short exposures, practically fallen into disuse for medical work. A great variety of motor-driven interrupters have been contrived, many of them employing a mercury jet operated centrifugally in methylated spirit, paraffin, or compressed coal gas. For heavy hospital work, induction coils and Wehnelt interrupters have lately been constructed to work at large amperages for use directly on direct-current supply mains at potentials up to 200 volts. With an alternating-current supply no interrupter is necessary, but some form of rectifier (e.g., the synchronous mercury-jet interrupter, the modified Wehnelt interrupter, the aluminium rectifiers, etc.) is inserted in the primary circuit which will transmit only one phase of the alternating current. The coil is thus used merely as a step-up transformer, and in the secondary circuit the Röntgen tube is shunted with a high-potential rectifier arranged so as to provide an easy path for those impulses which are in the wrong direction.

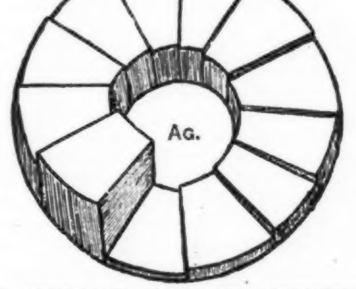


FIG. 2.—BENOIST'S RADIOCHROMOMETER.

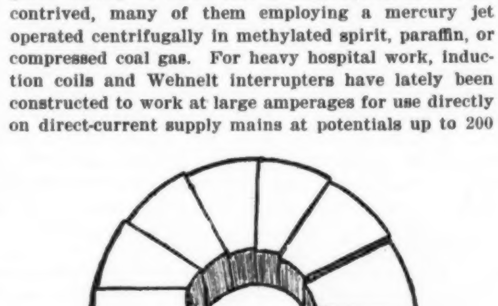


FIG. 3.

A, Radiator; *B*, maximum intensity of secondary rays; *C*, minimum intensity of secondary rays; *D*, primary X-rays; *E*, cathode rays; *F*, anticathode; *S*, slit.

The output of an X-ray tube has to be specified from the standpoints of both intensity and hardness. A rough notion of the intensity may be obtained by measuring with a milliammeter or thermo-galvanometer the actual current passing through the tube. But in practice the usual methods for measuring intensity depend on one or other of the properties of the rays—ionization, heating, fluorescing, photographic, or chemical. Owing to the delicacy and convenience of ionization methods, most recent workers have taken advantage of this property of the rays. The heating effects are small, and require sensitive detectors such as bolometers or radiomicrometers. In medicine various chemical reactions brought about by the rays have been suggested and employed as aids to dosage; for instance, the discoloration of various alkaline salts (Holzknecht, 1902), the liberation of iodine from a solution of iodoform in chloroform (Freund, Bordier, and Galimard), the darkening of a photographic plate (Kienböck), the browning of pastilles of barium platino-cyanide (Sabouraud and Noiré, Bordier), and the precipitation of calomel from a mixture of ammonium oxalate and mercuric chloride solutions (Schwartz). Recently the lowering of the electrical resistance of selenium, when exposed to the rays, has also been suggested for the same purpose.

An indication of the hardness of a beam of rays is afforded by the potential difference between the terminals of the tube; this may be measured by some form of high potential electrostatic voltmeter, such as Bergonié's, capable of reading up to 100,000 volts or more. Or, failing this, the length of the alternative spark gap may be noted. In air, at atmospheric pressure, each centimeter of a spark gap between brightly polished balls is equivalent to about 28,000 volts. For general all-round photographic work a useful spark length is about 15 centimeters. The most accurate way of determining hardness is to measure the absorption due to a definite thickness of metal sheet (preferably of low atomic weight), or, perhaps, better to note the thickness of sheet required to reduce the intensity of the beam to half value. Among radiographers Benoist's radiochromometer enjoys extensive use as a hardness measurer. It consists of a thin silver disk surrounded by a dozen aluminium sectors in order of increasing thickness. The Röntgen rays are sent through the instrument, and the observations consist merely in matching on a fluorescent screen or photographic plate the images cast by the silver disk against one of those from the aluminium plates; the thickness of the matching sector increases, of course, with the hardness of the rays. The chromometer is illustrated in Fig. 2. As will be gathered, the instrument is rapid in action, but from a quantitative point of view its readings may easily be misinterpreted.

It was formerly assumed that the absorbing powers of different elements for the Röntgen rays are, roughly, proportional to their densities. However, Benoist has shown that the elements of high atomic weight are a good deal more absorbent, weight for weight, than the lighter-atomed elements. For example, to quote the results of one experiment with hard X-rays in which all the plates had equal masses and the same area, lead was 22, tin 15, and copper 8 times as absorbent as aluminium. It should, by the way, be noticed in passing that a similar relation holds for the soft γ rays from radium; for hard γ rays a density law holds, and the absorption of unit mass per unit area is a constant for all elements; in other words, these very penetrating rays altogether ignore atomic structure.

The writer has shown that when the absorbing screen and the anticathode emitting the X-rays are of the same material, the absorption is relatively low in amount; in other words, the rays are specially penetrating to such a screen. This abnormal transparency can also be detected when screen and radiator have closely adjoining atomic weights.

As is well known, the rays from a coil-driven Röntgen bulb are heterogeneous in character. The higher penetrating power of a beam after passage through a metal sheet is usually ascribed to the removal of the softer components. However, Sagnac and, later, Walter have claimed that their experiments point to an actual transformation of the incident rays by the material of the screen. Barkla (October, 1908) has put forward a somewhat similar view. In the special case when screen and anticathode are of like metal the author has shown that in general an exponential law of absorption rules, indicative of homogeneity.

When X-rays encounter matter, two kinds of what are now known as secondary rays are the result. One of these consists of negatively-charged electrons which are emitted from the substance with a speed of about 7 by 10^9 centimeters per second (Innes, 1907). This velocity increases a little with the hardness of the rays, but does not depend upon their intensity. More of these secondary corpuscles emerge from an element of high atomic weight than from one of low.

* Knowledge.

The other class of secondary rays is of a kindred nature to the primary. With very soft primary rays most elements (especially those of low atomic weight) emit secondary rays almost identical in quality with the primary; the secondary rays may, in fact, be regarded as so much scattered primary radiation. With hard primary rays this scattered radiation disappears and is replaced by a soft homogeneous radiation specially penetrating to and characteristic of the element which emits it. The degree of hardness of the primary rays at which this transformation begins to occur depends on the material of the radiator.

The purely scattered secondary rays show a one-sidedness of polarization which Barkla first noticed in 1905. This, being interpreted, means that in a plane at right angles to the direction of propagation of the primary rays the secondary rays have a minimum intensity in a direction parallel to the cathode rays in the generating X-ray tube, and a maximum in a direction at right angles to this (see Fig. 3).

One may note that both classes of secondary radiation preponderate on the far side of a thin screen over the corresponding amounts which emerge from the near or "incidence" side.

Hagn and Wind (1901), by allowing Röntgen rays to pass through a very narrow triangular slit on to a photographic plate, obtained broadenings of the slit image, which they attributed to diffraction. Walter and Pohl have, however, very recently shown that the extent of the broadening depends on the time of exposure, and that the diffraction of the X-rays cannot be regarded as having yet been established.

Marx, in 1906, carried out determinations of the velocity of the Röntgen rays, and arrived at the result that it is equal to the speed of light. The result would be of the greatest importance if it were substantiated, but after Franck and Pohl's repetition of the experiments this year we are, however, forced to conclude that Marx's measurements cannot be relied upon to furnish the value of this constant.

The present position of the X-rays is interesting on account of the difference of opinion that prevails as to their nature. The ether-pulse theory regards them as so many individual electromagnetic disturbances, which travel outward through the ether with the speed of light whenever a charged particle has its velocity altered. In the front of each pulse are electric and magnetic forces at right angles to each other and to the direction of propagation. For a pulse to contain much energy the charged particle must be moving with a speed not far from that of light, and the alteration in its motion must be effected very suddenly.

On the neutral-pair theory the Röntgen rays consist of pairs or doublets made up of a positive and an equal negative charge, which possess rotational and a high translational velocity.

Both theories account for the penetrating abilities of the rays, their ionizing properties, the lack of deviation in electric and magnetic fields, the absence of refraction, and the other special properties with which we have dealt above. A good deal of the evidence that has been called upon depends on the different results arising out of secondary radiation; it cannot, however, yet be said that any of these results are of discriminating value. Accurate indications of velocity and diffraction would be of service, as ether pulses must travel only with the speed of light; material particles could have any speed less than this. No diffraction effects could be expected on the neutral-pair theory. However, the whole question has attracted attention, and we should not have long to wait before some crucial experiments are carried out to a successful conclusion.

For a fuller treatment of these and many other associated points the reader is referred to—

Sir J. J. Thomson, "Conduction of Electricity Through Gases," 2nd edit. (Camb. Univ. Press), 1906.

N. R. Campbell, "Modern Electrical Theory" (Camb. Univ. Press), 1907.

Sir Oliver Lodge, "Electrons" (Bell), 1907.

G. W. C. Kaye, "Röntgen Rays" ("Science Progress," October, 1908).

C. G. Barkla, "On Secondary Röntgen Rays" (Jahrbuch der Rad. und Elekt., V. 3, p. 346, 1908).

EARTHQUAKE FORECASTS.—I.*

FUTURE POSSIBILITIES.

BY G. K. GILBERT.

PLACE.

LET us consider first the possibility of scientific forecast as to place, and in so doing let us assume the point of view of the resident. The factor in which he is personally interested is the factor of danger—danger to life, danger to property, danger to the present generation. Except as a matter of curiosity, he is not concerned with faint tremors and minor shocks, nor with violent shocks likely to come after centuries of immunity. It will be convenient, at least for this day and hour, to embody our point of view in a concise term, and the adjective *malloseismic* will be used to designate localities likely to be visited several times in a century by earthquakes of destructive violence.

Experience.—The most important of all bases for the indication of earthquake localities is experience. Where tremors have been frequent in the past, there they are to be expected in the future. This premise hardly requires discussion, for it is founded on our confidence in the continuity of the great processes concerned in the evolution of the earth. We recognize indeed that continuity may fail in any particular case, but we always assume it as far more probable than discontinuity.

Other bases for forecast are connected with our conceptions as to the origin of earthquakes. The theory of earthquakes now generally accepted ascribes them to the sudden breaking or slipping of rocks previously in a condition of shearing strain. Exception should probably be made of some of the shocks accompanying volcanic eruptions, but volcanic shocks constitute a class by themselves to which it is not important to extend the present discussion. In non-volcanic, or ordinary examples, it is believed that the strains arise in connection with those tectonic or diastrophic changes which are exhibited superficially in the deformation of the surface, and that their accumulation is gradual. Fracture occurs when and where the internal stress exceeds the strength of the rock, and a fault results. Slipping takes place when the stress along the plane of a pre-existent fault exceeds the force of adhesion. In either case it is the instantaneous character of the separation which occasions the jar.

The earthquake being thus a concomitant of tectonic change, its regions of frequency should be found in areas of diastrophic activity, and its occurrence should be rare and sporadic in areas of diastrophic sluggishness. This corollary is so well recognized that seismic activity is commonly regarded as the specific criterion of relatively rapid crustal change. Other criteria of such change are physiographic and geologic, and these may be applied in regions whose earthquake history is unknown. They may also be used, in the absence of seismic records, to give approximate indication of malloseismic localities.

Bold and High Ranges.—It was pointed out by Powell that, because erosion is greatly stimulated by altitude and high declivity, lofty mountains must be regarded as young; and under the principle of continuity young mountains created by uplift are presumably still growing. They are, therefore, phenomena of diastrophic activity and presumably belong to malloseismic districts. The conspicuous example is Mt. St. Elias, which rises boldly 20,000 feet from its base, which was shown by Russell to have continued its growth during the life of the existing marine fauna, and which recently has been signalized by earthquakes of the first class.

Fault Scarps.—Along the bases of block mountains the lines of their limiting faults are sometimes marked by fresh scarps demonstrating recent increase of uplift. In the Great Basin these scarps traverse the alluvium of the piedmont slopes, a surface of such simple type that their presence or absence can be observed with confidence. Their absence suggests diastrophic inactivity or sluggishness, for their effacement is a time-consuming process. Their presence suggests diastrophic activity, and the suggestion is strengthened when their relation to phenomena of weathering and erosion is such as to show that they were produced by a series of recent uplifts instead of one only.

Rifts.—A third physiographic criterion is illustrated in California and was brought to general attention by the San Francisco earthquake. The slip causing that shock occurred on the plane of a fault which outcrops at the surface and has been traced for hundreds of miles. The attitude of the plane is vertical, but the displacement along it was horizontal; and there is reason to think that earlier movements on the same plane were horizontal also, for the fault does not separate a ridge of uplift from a valley of depression, but traverses both valleys and mountains. At all points it is included within a belt of peculiar topographic habit, which the investigating geologists have designated as "the rift." Within this belt, which ranges in width from a fraction of a mile to several miles, are numerous ridges and troughs, long or short, level or inclined, and approximately parallel to the trend of the belt. Each of these represents a dislocated tectonic block, and the dislocation is of so recent date that the disturbed drainage has made little progress toward the restoration of normal conditions. Lakelets are numerous, and streams wander irregularly. Without delaying to attempt a fuller and more adequate description, which may be found in the report of the California Commission,* I content myself with an assurance to physiographers that the topographic expression of the rift belt is distinctive, so that it can readily be recognized in other localities by those who have made its personal acquaintance in the field. Other belts of the same character have already been found in California* and their discovery elsewhere may confidently be expected.

Rift topography appears to be the surface expression of a species of repetitive horizontal faulting, just as the fault scarp is the surface expression of vertical faulting, and the two types, which with present knowledge are apparently distinct, will doubtless eventually be found to intergrade. The features of the San Andreas rift—the one associated with the San Francisco earthquake—were neither created nor greatly modified at the time of that shock, but such modifications as were made were of such character as to accentuate and perpetuate the peculiarities of the belt. The belt itself would be the natural result of a long series of such events, succeeding one another with such rapidity as to dominate minor aqueous agencies in the modeling of the surface. These considerations, together with the fact that earthquakes are known to have repeatedly originated in the rift belts of California, serve to establish the rift topography as a criterion for the recognition of malloseismic districts.

Geologic Formation.—Fault scarps and rift belts serve to indicate some of the foci of past and future earthquakes. Other foci lie wholly within the earth's crust. Whether the rupture occurs above or below, its jar is propagated through the crust in all directions and affects a large area of the surface. Within this area the intensity of the shock varies primarily with distance from the origin, but it varies also with the character of the geologic formation at the point of emergence. The variation with formation has less range than the variation with distance, but is not less important to the resident and the sojourner, the architect and the engineer—that is to say, it is equally important in forecasting areas of dangerous energy. The portion of San Francisco most intensely racked by the shock of 1906 stood farther from the fault line than the portion least affected, but it stood on less coherent soil. Wood has carefully mapped the distribution of intensity in the San Francisco peninsula, as evidenced by the injury to buildings, and shown its close correlation with the distribution of underlying material;† and similar, though less detailed, correlations have been made in other regions. On the theoretic side the

* Abstracted from Presidential address to the American Association of Geographers.

* California earthquake of April 18, 1906; report of the State Earthquake Investigation Commission; published by the Carnegie Institution, Washington, 1908, pp. 25-52.

* The only rift belt besides the San Andreas which has yet been traced for any distance is one which follows in a general way the western base of the Berkeley Hills. In the vicinity of Oakland its position is indicated by a trough among the lower hills two or three miles back from the piedmont plain. At Haywards it coincides with the western base of the hills, and at Irvington, with the western base of a projecting spur. In Berkeley also its line follows the base of the hills, but a little northward it climbs to the summit of the first ridge. The principal fault occasioning the earthquake of 1868 was in this rift belt, running from Haywards southward, and it is probable that some of the earlier recorded earthquakes were associated with the same belt. The fault of 1868 is described, and the rift belt is mentioned, in the "Report of the California Earthquake Commission," Vol. I., Part II., pp. 434-5 and 447.

† Report of the California Earthquake Commission," Vol. I., Part II., pp. 220-45, and atlas, maps 17-19.

subject is almost untouched, and there is great need of experimentation, but the empiric results already available have much practical value and enable the geologist and engineer to distinguish broadly, within the limits of a malloseismic district, the tracts more likely, and the tracts less likely, to be affected disastrously by the passing earthquake wave.

On the whole that factor of earthquake forecast which consists in the indication of locality is in a satisfactory condition. In long inhabited regions experience designates certain districts as malloseismic. Newly settled regions may be classified, provisionally and less perfectly, by the data of physiography. And malloseismic districts will eventually be subdivided with confidence by means of geologic criteria.

TIME.

Turning now to the time factor in forecasting, and retaining the point of view which emphasizes the element of danger, let us inquire what methods are available for the prediction of the time of occurrence of a destructive earthquake at a given locality or in a given district. Rational attempts to solve this problem have been connected (1) with the idea of rhythm, (2) with that of alternation, (3) with that of the trigger or starter, and (4) with that of the prelude; and each of these lines of approach is worthy of examination.

Rhythm.—Because we are surrounded by and immersed in the rhythms of art and nature, and because the earthquake is a recurrent phenomenon, it is easy to infer that the interval between the last shock and the next will be similar to that between the last and its predecessor. Reasoning of this general tenor probably underlies the greater number of lay forecasts, and is in particular responsible for the wide-spread popular belief that a place recently devasted is *ipso facto* immune for several years. A similar belief prevalent among men of science has a slightly different origin, but is even more strongly held; and there is little exaggeration in saying that our guild recognize it as a duty, when the terror-stricken inhabitants of a racked and ruined city seek safety in the open spaces, to assure them that the danger is past and urge them to return to their homes. Now, it is not at all true that either the great shocks affecting a particular locality, or affecting a district, or affecting the earth as a whole, are separated one from another by regular or approximately regular intervals; and it is not at all true that immediate danger is past when a great shock has wrought its havoc; and yet I am prone to believe that the rhythmic principle does hold place in the mechanics of earthquakes. On that point something further will be said, but I shall first invite your attention to the general phenomena of earthquake sequence, selecting examples from the American record because we are most interested in the phenomena of our own territory.

The United States has one well-known malloseismic district, a district including central and southern California, with areas in Mexico and the Pacific Ocean, and possibly extending northward. Alaska also contains a district, and there may be a third in Utah. Since the beginning of the last century, Alaska has experienced at least nine shocks of destructive rank; but the record is fragmentary and may omit more than it includes. For the California district eleven are listed, within the same period, the record being somewhat vague, and possibly incomplete, for the first half of the century. To these we may tentatively add the Oregon or Klamath earthquake of 1867 and the Sonora and Arizona earthquake of 1887, raising the number to thirteen. In other parts of the United States were the New Madrid (1811-12), the Charleston (1886), and a relatively weak but probably destructive shock in the New Madrid region in 1865.

The average interval between the individuals of the California series was nine years, and the separate intervals, in order, were: 12, 24, 3, 18, 8, 2, 1, 4, 15, 5, 6 and 8 years. As the centers of disturbance were scattered through the whole district and the areas of dangerous violence were of moderate dimensions, the danger record for any single locality was smaller, and the intervals correspondingly larger. In San Francisco, for instance, the last five destructive shocks have been separated by intervals of 26, 3, 30 and 8 years.

While it is manifest at once that neither of these sequences constitutes a rhythm, it is quite conceivable that they represent in some way a system of rhythms. They might, for example, be composed of several independent rhythms, each beating with its own period; or they might contain imperfectly recorded rhythms, each requiring for its interpretation some of the less violent shocks not included in the destructive class. And if it were possible to group the shocks according to place of origin, it might be found that each earthquake center has its orderly law of sequence. But while the existence of such a systematic arrangement seems within the range of possibility, I regard it as altogether outside the field of probability; and I feel sure that any attempt to discriminate rhythmic series on numerical grounds, without any other basis for classification, would prove unprofitable.

The single element of order which unquestionably belongs to the sequence of quakings is implied by the term after-shock. Every great shock is followed by a train of minor shocks, the length of the train being roughly proportional to the magnitude of the initial shock, and the average strength and frequency of the shocks diminishing with the lapse of time. Usually also the great shock is preceded by faint tremors, or by a few small shocks. The prelude, the great shock and the train of after-shocks, together constitute a typical seismic event, and if their sequence could be absolutely depended on, the terror of the great shock might rationally be palliated by the thought that the worst is over. But unfortunately, there are exceptions, and the character of the exceptions is not reassuring. Occasionally the prelude includes a shock of great power, and occasionally the train of after-shocks, instead of being wholly subordinate in intensity, includes one or more major shocks, rivaling the initial shock in violence. Of the twenty-five American examples fourteen were normal and two abnormal, the others remaining unclassified because too little is known of them. It is possibly significant that the two abnormal earthquakes were of exceptional power, the New Madrid heading the list for the United States, and the Yakutat, of Alaska, being of the same order of magnitude. The New Madrid event began with a shock of great violence at 2 o'clock on the morning of December 16, 1811, and this was followed by a long series of vigorous after-shocks, among which eight were noted as of special strength and three were reported as equaling or exceeding the initial shock. Of the last-mentioned, one followed the initial shock after an interval of five hours, and the others severally after 38 and 53 days.* The Yakutat series began with a strong shock September 3, 1899, "and there were shocks at intervals until September 10, when, at 9.20 A. M., they began to be alarming. There were fifty-two shocks, culminating in one of great violence at 3 P. M. . . . There was another violent earthquake September 15 and other shocks until September 20."†

In view of these facts the promptings of terror when a great shock comes may well be seconded by the admonitions of wisdom, for even though it be probable that the worst is over, a substantial possibility remains that the worst is still to come. American experience suggests that as often as one time in eight a powerful shock, instead of being the climax of the earthquake, may be only the forerunner of the climax; and when life and limb are at stake the odds of seven to one in favor of safety form but a slender basis for mental serenity.

Turning now from the statistics of sequence to the question of underlying causes, I wish to present a conception of earthquake mechanism which has developed gradually during the study of California phenomena. The block movements associated with earthquakes in California are dominantly horizontal, and the fault planes along which the blocks slide are vertical. For this reason my mental picture of the system of faults (habitually drawn with two dimensions only) is a map instead of a section on a vertical plane. Imagine a large tract of the earth's crust superficially divided by faults into acute-angled blocks, which have a prevailing trend in one direction. In composition the blocks are heterogeneous, including stratified, metamorphic and igneous rocks, with complicated structure. The fault surfaces are not mathematically plane, but gently undulate, so that movement among the blocks involves more or less distortion of the blocks themselves. Imagine also that the tract is subject to external horizontal force of such nature as to induce internal shearing strains and the associated shearing stresses; and that the application of external force is continuous, making the internal stress cumulative. The internal stress is not uniformly distributed, because the more plastic rocks relieve the strain by flowage. When the stress along some part of a fault surface becomes greater than the adhesive force a slip occurs. When the stress within an elastic rock becomes greater than the shearing strength fracture takes place. In either case there is an instantaneous redistribution of stress. Relief of stress in the rock adjacent to the rupture is accompanied by increase of stress about the edges of the surface of parting, with the result that the area of the parting grows; and the growth is continued until regions of small stress are reached. The magnitude of the resulting earthquake depends chiefly on the quality of energy released by the relief of accumulated strain and stress.

If the quantities are large there are important after-effects. The discharge of strain causes a new arrangement of strains and stresses through a large tract; this leads to flowage and the local concentration of stress, especially in the more elastic rock; and this in turn causes fractures, of which the surface manifestations are after-shocks.

* MS. of report on New Madrid earthquake by M. L. Fuller.

† "Recent Changes of Level in the Yakutat Bay Region," by R. S. Tarr and Lawrence Martin, Bulletin Geol. Soc. Amer., Vol. XVII., p. 31.

When finally equilibrium is restored, and the train of after-shocks is complete, the system of stresses, not only in the immediate neighborhood of the fault, but throughout an extensive tract, is materially different from what it was before the earthquake. In places, and especially near the fault, the general stress is less; in other places it is greater. The region of maximum stress is ordinarily shifted, so that when stresses imposed by external force again overtax the resistance, the new point of yielding is at some distance from the last.

In view of the complexity of the conditions and the intricacy of the interaction among strains, it is not to be supposed that the status at any one epoch will ever be exactly repeated. Nevertheless, its main features may recur, and whenever they do a cycle will have been completed. Such a cycle, however, would be indefinitely long, and would be too difficult of discovery to be available for purposes of forecast.

It is conceivable also that in some limited portions of the general district the local conditions may give rise to repetitive collapses somewhat independent of the general progress of events. In such case the successive earthquakes would originate in the same place and their systematic character could be recognized through that fact.

There is a class of natural and artificial rhythms in which energy gradually passes into the potential form as internal stress and strain and is thus stored until a resistance of fixed amount is overcome, when a catastrophic discharge of energy takes place. The supply of energy being continuous and uniform, the discharges recur with regular intervals. The frictional machine for generating electric sparks in the laboratory is the type; other examples are the geyser, water gurgling from a bottle, and the alternate adhesion and release of the violin bow in contact with the string. The earthquake is a repetitive catastrophe belonging to the same mechanical group, and if its mechanism were as simple as that of the electric machine its rhythm would be as perfect. If the stresses of an earthquake district affected only homogeneous rock and were always relieved by slipping on the same fault plane, the cycle of events would be regular; but with complexity of structure and multiplicity of alternative points of collapse, all superficial indication of rhythm is lost. If rhythmic order shall ever be found in the apparent confusion, it will be through an analysis which takes account of the points of origin of all important shocks.

(To be continued.)

A Milan commission has during a number of years considered and determined the organic differences between the silks obtained from different districts; special consideration was given to those properties which were of importance in the application of the silks to manufacture. Specimens of silk from the different districts of Italy, France, the Levant and Asia Minor, China, Japan, and other parts of Asia, besides samples of wild silks were examined. Determinations were made of: (1) physical constants, and (2) chemical data, such as the quantity of fibroin, sericin, and fatty matter, the melting point of the fatty matter, the ash, etc. The results obtained, however, do not explain the different dyeing properties of the silks. The samples resisted in different degrees the action of acids and alkalis, and the amounts of metallic mordants taken up depended on the time and the manner of the cultivation. The principal reagents which affect silk during dyeing are the acids and alkalis used in the dye-baths. To study these actions the degummed samples were treated with: (1) 5 per cent solution of sulphuric acid, and (2) a solution of potassium hydroxide containing 1.2069 grammes per liter; the weights of the solutions taken were in each case five times the weight of the silk, and the silk was digested with the reagent for 24 hours at a temperature of 27 deg. C. The silks were then washed, weighed, and again treated. The loss in weight during each digestion of twenty-seven samples of silk was determined. Degummed silk always contains a certain amount of fatty acid, so that the first figure obtained with the alkali was too high. The effect of mordanting was tried with the chlorides of iron, aluminium, chromium, and tin; the results obtained show notable differences. The samples of degummed silk were given three baths of stannous chloride solution of 28 deg. B. for one hour, and after each bath the silk was immersed in sodium carbonate solution at 5 deg. B. at 40 deg. C. for one hour. The amounts of tin oxide taken up by the different fibers were determined. The silks of Bengal and Canton show the least attraction for the mordant; these silks are of different colors but from similar cocoons. Similar results were obtained when other fixing agents in place of sodium carbonate were used. Some of the Bengal silks do not show the peculiarity mentioned and the differences disappear when raw instead of degummed silks are used. The peculiarity mentioned is not due to the presence of lime on the fiber in the state of a calcium soap, for other experiments were performed in which a treatment with hydrochloric acid

was resorted to. To trace the effect of lime, the samples of raw silk were boiled with a 20 per cent solution of calcium acetate for one hour, washed, and then treated with stannous chloride. The sample treated with the calcium solution took up considerably more of the tin salt than the untreated samples.

ELECTRICAL NOTES.

In order to mitigate the pest of caterpillars which is creating such havoc in defoliating the forests of Germany, a novel expedient has been adopted. The irresistible fascination of the candle-flame to the moth is well known, and entomologists are aware that street electric arc lamps afford a happy hunting-ground. The German authorities have turned this point to advantage. An electric light is erected on a suitable tower, beneath which is a deep, funnel-like vessel carrying powerful revolving exhaust-fans. These electric lights are fitted with powerful reflectors, which project the light in two well-defined rays upon the dark background of the forest, half a mile away, in much the same way as the beams of a searchlight. The result is described as remarkable. The hordes of brown moths that lay the eggs producing the caterpillars in such enormous quantities, dazzled by the light, come fluttering hastily toward its source. As they near the lamp they become caught in the vortex set up by the revolving fans, are sucked up and swept through the funnel into a suitable receiver, subsequently being destroyed in the furnaces. So eminently successful was the first night's experiment, when some three tons of moths were caught, that another similar installation is being erected. Though the defoliation of the trees may not be completely arrested, this wholesale destruction of the plague will certainly result in a heavy diminution in the ranks of the caterpillars, and the timber will be saved.

Faraday had discovered so far back as 1845 that numerous bodies, not magnetic in the ordinary sense, were nevertheless affected by powerful magnetic fields, but it was not until 1896 that this principle was applied to the separation of minerals by J. P. Wetherill. He succeeded in separating a series of minerals, all very feebly magnetic, from the somewhat more feebly magnetic zinc oxide and other zinc ores of New Jersey by the use of very powerful magnetic fields, produced by means of electromagnets with wedge-shaped pole-pieces, and since his original invention this principle (the magnetic separation of non-magnetic material, as it is sometimes called) has found an extended application, one of the most recent being the magnetic concentration of specular hematite by the Edison deflection method, using pole-pieces of the Wetherill type. Such separation as that of tungsten from tinstone, of raw spathic ore from zinc blende, of garnets from silver ore, which are necessary before any rational metallurgical treatment of the ores is possible, but which offer insuperable difficulties to the ordinary methods of dressing, have been rendered possible by the adoption of the Wetherill principle. I may point out that no successful wet separator for feebly magnetic minerals has yet been devised; this is a problem presenting numerous difficulties, but probably quite capable of solution, and at the same time very well worth solving.

Electrolytic copper, once produced only in Germany, France, and England, has since 1880 been made in large quantities in the United States, which now furnishes annually 346,000 tons, or 86¼ per cent of the world's output of refined copper. The discovery of copper deposits in Australia and Russia has created refineries in those countries. A new process, patented by Lachinsky, is employed at Boleslav, Russia. The ore, which contains from 15 to 45 per cent of copper, is carefully separated from the gangue, ground, and sifted to a size of 1/25 inch. It is then mixed with clay and formed into bricks, which are roasted. This is one of the peculiarities of the process. The oxide of iron formed in roasting the bricks does not dissolve in the acid bath and the principal difficulties attending other methods of this class are thus avoided. The material is then treated with a 5 per cent solution of sulphuric acid in lead-lined vats. The solution obtained contains 5 per cent of copper and 1 per cent of free acid. It is filtered and then electrolyzed in cubical wooden vats lined with lead and provided with stirring apparatus. Each vat measures 40 inches every way, contains nine anodes of lead, ⅛ inch thick, and eight cathodes of sheet copper, takes a current of 900 amperes at from 2 to 5 volts, and deposits about 50 pounds of copper in 24 hours. The anodes are inclosed in canvas bags which not only prevent the copper from redissolving from the cathodes after the action has continued a certain time, as occurs in other electrolytic processes, but also, in some unexplained way, prevents the oxidation of ferrous sulphate to ferric sulphate and insures nearly the theoretical yield of copper, 17.7 grains per ampere hour. The success of the Boleslav plant has led to the construction of a larger one in the vicinity. A plant producing one ton of copper per hour can be constructed for $24,000.

ENGINEERING NOTES.

As the result of various improvements in the last few decades, the whole trend of modern mining is toward the utilization of large deposits of low-grade material, the increased scale of operations enabling economies to be effected that were impossible while small quantities alone were dealt with. One of the cardinal problems that will confront our successors will be how to work with profit minerals of lower grade than any that we have yet attacked, so as to enable the miner to include within his sphere of operations deposits too poor for us to deal with to-day.

It is reported that the viceroy of Pechihli has submitted to the Chinese government a proposition to reconstruct the Great Canal from Pechihli, through Shantung, to Kiangsu, in accordance with the demands of modern commerce. The realization of this project would facilitate steamboat traffic and the conveyance of the mails. More than $200,000 per year were formerly expended on this canal, which carried the tribute of rice from the southern provinces to Pekin, and its maintenance still costs $40,000 annually. As the canal is an important internal waterway connecting the northern and southern parts of the empire it would be better, in the viceroy's opinion, to expend a considerable sum in deepening and improving it so thoroughly that no additional repairs would be required for several years. If the imperial government consents to the plan, the cost will be borne by the provinces of Pechihli and Shantung. The great merchants of China are unanimous in desiring that the canal shall be rebuilt and provided with dikes. European dredges and operators will be indispensable for the work, the cost of which is estimated at more than $400,000.

Bulletin No. 26, "High Steam-Pressures in Locomotive Service," has just been issued by the University of Illinois Engineering Experiment Station. It is an abstract of a report upon the same subject, which was published last year by the Carnegie Institution of Washington, D. C. It summarizes the results of one hundred locomotive tests conducted by Dr. W. F. M. Goss under the patronage of the Carnegie Institution in co-operation with the authorities of Purdue University. The tests were run in six different series, the boiler pressures for the several series varying from 120 pounds to 240 pounds. The results presented include concise statements concerning the effect of changes in boiler pressure upon power capacity and upon steam and coal consumption per unit power developed. The general question is discussed as to whether a possible increase in the weight of a boiler should be utilized by making the boiler stronger that it may carry a heavier pressure, or by making it bigger that it may have more heating surface. The conclusion of this discussion, based upon data presented, is to the effect that single-expansion locomotives using saturated steam are most efficient when operated under a boiler pressure of 180 pounds; that when this limit of pressure has been reached, any further increase in weight which may be possible should be utilized in securing increased boiler capacity rather than higher boiler pressures. Copies of this bulletin may be obtained gratis upon application to the director, Engineering Experiment Station, Urbana, Ill.

The buildings necessary for carrying out what will prove to be a new chemical industry in this country are approaching completion in the Midlands. Here the ingenious process discovered by Dr. C. F. Wülfing for the production of a new and valuable blue-black paint for preserving iron will be commercially exploited. The value of this chemist's invention is that not only does it provide a new and highly valuable and inexpensive protective medium, but it is prepared from what has hitherto been practically a useless by-product from another manufacture—the hydrochloric acid pickle used for the preparation of iron plates for tinning. In the Welsh tin-plate trade two such pickles are used, one made of sulphuric and the other of hydrochloric acid. The first-named, after its primary work is completed, is employed in the production of copperas, but hitherto the last-named solution has defied commercial utilization. Dr. Wülfing, who resided for many years in the center of the tin-plate industry in the principality, turned his attention to the question, the scope of his idea being to precipitate the oxide of iron by a cheap and commercially practicable process. There are certain agents which can effect this end, but although the oxide of iron is obtained, the precipitating substance employed in itself becomes useless. It occurred to this chemist that ammonia might be profitably adopted, especially since not only would the iron oxide be secured, but the resultant ammonium chloride obtained from the process would be more valuable than the ammonia used. He experimented on these lines, and finally succeeded in discovering a means of carrying it out profitably and without any appreciable loss of ammonia—one of the most difficult objects to achieve, bearing in mind its volatile nature. The iron oxide obtained is of a beautiful blue-black color, absolutely insoluble in water, of excellent quality, and chemically pure. The paint is made up by mixing the oxide with boiled linseed oil. That it is an excellent preservative for ironwork has been proved conclusively. Structures which were treated therewith two years ago, and continually exposed to the varying weathers, have a surface as fresh, perfect, and as varnish-like as when first treated.

SCIENCE NOTES.

In the production and exportation of ochers France now surpasses Saxony, Italy, and Bohemia, and leads the world. Most of the French ocher comes from Burgundy and Vaucluse. The Burgundian ocher is the most esteemed and its exportation would be largely increased but for the exorbitant duties imposed by Italy, the United States, and Russia. In spite of these duties, however, the superiority of French ochers causes their exportation to increase steadily. The total quantity produced is about 40,000 tons, of which nearly half is exported.

In certain conditions sulphuric acid oxidizes hydrogen, producing water and sulphur dioxide. With impure hydrogen this reaction takes place at atmospheric temperatures, but with perfectly pure hydrogen a high temperature is required. At 345 deg. F., at constant pressure and with an excess of sulphuric acid, the reaction is mono-molecular. The reaction velocity is not appreciably affected by variation in the strength of the acid from 91 to 97 per cent by the presence of alkaline sulphates or by exposure to light, but it is accelerated by metals of the platinum group, gold, selenium, various soluble sulphates, oxides of antimony, arsenic, and tantalum, and retarded by oxides of vanadium, molybdenum, and tungsten, insoluble sulphates, and silica.

In 1870, through the medium of the public press, Mr. John Hampden wagered £500 ($2,500) that the convexity of the surface of any inland water could not be proved. Alfred Russel Wallace accepted the challenge. The old Bedford Canal was chosen for the experiment and a six-mile stretch between two bridges selected as the site. On the higher of the two bridges a white sheet, six feet long and three feet wide, was fastened. Along the center of the sheet parallel to the water was a six-inch black band, the lower edge of which was at the same height above the water as the parapet of the second bridge. At the half-way point a pole with two red disks, four feet apart, was erected in such a way that the center of the upper disk was at the same height as the center of the black band. A six-inch telescope, resting on the parapet of the second bridge, was used for sighting. As seen through the telescope, both disks appeared above the black band on the sheet. Were the earth flat, the top disk would have appeared exactly on the same level with the band. A second experiment was performed with a spirit level. The sequel is almost as interesting as the experiment. The referee for Mr. Hampden, a devotee of the flat earth school, insisted, on looking through the telescope, that the three points were in a straight line. Hampden, who refused to look through the instrument, accepted the statement, although Wallace's referee declared that the curvature was shown. An umpire, chosen to settle the difficulty, awarded the money to Wallace. Then followed a remarkable series of libels, persecutions, and recriminations. As late as 1885 Hampden published, among other things, the statement that "no one but a degraded swindler has dared to make a fraudulent attempt to support the globular theory." Wallace sums up his experience in this matter thus: " . . . two law suits, the four prosecutions for libel, the payments and costs of the settlements amounting to considerably more than the £500 I received from Hampden, besides which I bore all the costs of the week's experiments, and between fifteen and twenty years of continued persecution." The whole story as presented by Wallace is a most astounding series of libels, against which he seemed to have been utterly powerless.—Robert L. Brown in Science.

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